This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

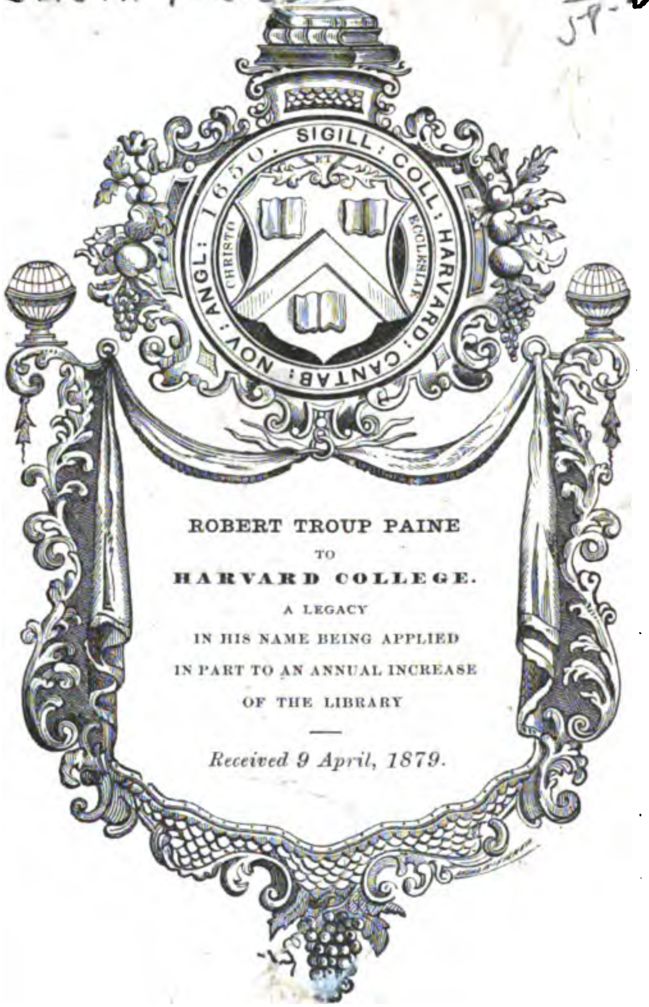
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Chem 428.30.2

140/58



ROBERT TROUP PAINE
TO
HARVARD COLLEGE.
A LEGACY
IN HIS NAME BEING APPLIED
IN PART TO AN ANNUAL INCREASE
OF THE LIBRARY

Received 9 April, 1879.

ELEMENTS

OF

CHEMISTRY,

IN THE

ORDER OF THE LECTURES GIVEN

IN

YALE COLLEGE.

BY BENJAMIN SILLIMAN,

PROFESSOR OF CHEMISTRY, PHARMACY, MINERALOGY AND GEOLOGY.

Robert Troup Paine
to
IN TWO VOLUMES.
Harvard College

VOLUME I.

NEW HAVEN:
PRINTED AND PUBLISHED BY HEZEKIAH HOWE.
1830.

~~F566~~
Chem 428.30.2
-3.
1879, April 9.
Prime bequest.
(Vols I, II.)

BOUND FEB 2 6 1910

DISTRICT OF CONNECTICUT, ss.

L. S.

Be it remembered, That on the eighteenth day of February in the fifty fourth year of the Independence of the United States of America, Benjamin Silliman, of the said District, hath deposited in this office the title of a Book, the right whereof he claims as Author in the words following, to wit:

"Elements of Chemistry, in the order of the lectures given in Yale College. By Benjamin Silliman, Professor of Chemistry, Pharmacy, Mineralogy and Geology. In two volumes."

In conformity to the Act of Congress of the United States, entitled, "An Act for the encouragement of learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the times therein mentioned." And also to the Act, entitled, "An Act supplementary to an Act, entitled, 'An Act for the encouragement of learning, by securing the copies of Maps, Charts, and Books, to the Authors and Proprietors of such copies during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

CHARLES A. INGERSOLL,
Clerk of the District of Connecticut.

A true copy of Record, examined and sealed by me,

CHARLES A. INGERSOLL,
Clerk of the District of Connecticut.

PREFACE.

THE object of this work is to present the science of Chemistry in the most intelligible form, to those who are learning its elements; and for the convenience of the classes in Yale College, the topics are arranged in the order in which they are now discussed, in the lectures given in that Institution. As the Medical Class constitutes a part of the audience, the most important pharmaceutical preparations, and leading uses of such substances as belong both to the Materia Medica, and to Chemistry, are briefly mentioned; and in general, throughout the work, practical facts are interwoven with scientific principles. The attempt has been made, to unite copiousness with condensation; perspicuity with brevity; and a lucid order, and due connexion of subordinate parts, with a general unity of design.

By numerals* and letters, the topics have been digested under appropriate heads; and by the use of large and small capitals, and italics, the writer's impression, as to the relative importance of the leading facts and propositions, has been indicated.

It is supposed that these mechanical helps, not novel indeed, but in this work, more extensively employed than usual, may facilitate the progress of the student, by enabling him to take, at pleasure, a more general, a more particular, or a detailed review; and the same facility is, of course, presented to the instructor.

Exact accounts of processes and manipulations have been given; and Dr. Hare, having kindly permitted the introduction of the cuts,† from his Compendium, his own language, sometimes abridged, has been generally employed in the descriptions of his figures. The valuable illustrations, thus derived from his liberality, render it unnecessary to apologize for the frequent use of his name.

---

* Adopted, to some extent, by Dr. F. Bache, in his System of Chemistry for Medical Students, and more fully by Dr. Henry.

† The more complex figures have been omitted.

The materials of this work have been gradually accumulating since 1802. They have been drawn from Scientific Journals, from the Transactions of Learned Societies, and from the principal writers who have flourished since the middle of the last century—*the Augustan age of Chemistry*. From works of an earlier date, light has been occasionally derived, as well as from notes and recollections of the instructions of the distinguished teachers, to whom the author was formerly so happy as to listen. In this view, he takes particular satisfaction in naming the late Dr. Murray, of Edinburgh, and Prof. Thomas C. Hope, still a distinguished ornament of the University in the same city.

Various notices, derived from the author's own experience, and from his personal communications with others, are introduced, with occasional figures, for illustration; and in the notes, many miscellaneous facts are preserved.

In the immediate preparation of this work for the press, the original memoirs of authors and discoverers have been often consulted, and the abstract has been frequently drawn from them, rather than from the elementary books; but the analyses contained in the latter have not unfrequently been adopted; sometimes even after a careful examination of the original, and for this reason, among others, that the statements contained in them could be often, without injury, still farther abridged. In such cases, several eminent elementary writers have been diligently compared, on the same subject; and thus omissions have been supplied, and obscurity has been removed, either by the comparison, or by resorting to the first record.

References to the original memoirs have always been preserved, where such memoirs were attainable; and when the books containing them were not at hand, the citations have been copied from the latest systematical writers. Credit has also, in most instances, been given to elementary writers, for materials drawn from their pages; but for brevity, and especially where the facts are the common stock of the science, the references have been sometimes omitted, or an initial letter only retained. There are, however, some works to which a more particular acknowledgment is due. Those of Bergman and Scheele; the Lectures of Dr. Black, by Robison; the System of Dr. Thomson, in all its editions, and also his more recent work on the First Principles of Chemistry; the Dictionaries of Nicholson, Aikins, and Ure, the Compendium of Dr. Hare, the Dispensatory of Dr. Coxe, the Technology of Dr. Bigelow, the Operative Chemist of Gray, and the Chemical Manipulation of Mr. Faraday; the System of the late Dr. Murray, and his Elements, ably edited by his son; as also the writings of Mr. Dalton; the works of Lavoisier, Chaptal, Berthollet, and Fourcroy, the System of Thénard, in its most recent edition, and his miscellaneous writings, especially in connexion with Gay-Lussac; and those of Dr. Priestley, Bishop Watson, Mr. Parkes, Prof. Berzelius, and Sir H. Davy, including also his Elements—these are among the leading authorities, although it would be easy to increase the catalogue.*

A recent work by Dr. Turner, of the London University, has been of great utility. It is highly scientific and very exact, particularly on the facts and doctrines of definite and multiple proportions, and combining equivalents; and many of its details have been adopted.

But the work to which, more than to any other, the author of this is indebted, is the Elements of Dr. Henry. All its numerous editions have been attentively studied, and among the facts that have been cited from it, the statements of the proportions of bodies, and especially of the salts, are the most prominent. In numerous critical comparisons, made between it and the original memoirs, abundant evidence has been obtained of the great exactness of the respectable author, whose abstract always reflects an image of the original, diminished indeed, but perfect in every feature. No writer on chemistry, in the English language, surpasses Dr. Henry in fidelity, perspicuity and good judgment. For twenty years, his work was the text book of the classes in this Institution, and it ceased to be used here only when, on account of its increased size and cost, it ceased to be reprinted. Three editions† of it with notes, were published expressly for the students of Yale College; there have been three English editions since the latest American,‡ and the author's eleventh, with his last revision, has, through his kindness, been just received.

---

* Many French as well as English Journals of Science have been also examined.

† Besides two subsequently, by Professors Coxe and Hare, of the Univ. of Penn.

‡ Since it has become difficult to obtain this work, the valuable Manual of Dr. Webster, on the basis of Brande, has been recommended to the classes. Few works on Chemistry contain so much important information.

To the following gentlemen, the author of this work tenders his acknowledgments; to Prof. Edward Hitchcock and Prof. J. W. Webster, who were consulted in the revisal of the earlier proofs; but to Professors Griscom, Torrey and Olmsted, and to Mr. C. U. Shepard, assistant in the chemical department of Yale College, a more particular expression of thanks is due, for the trouble which they, by request, have taken, in reading nearly all the proofs. Their individual suggestions are occasionally designated; and while the work has been much benefitted by their judicious criticisms, they are fully exonerated from any responsibility either for its errors, or its deficiences. The errors that have been detected, and which were of such a character as to affect the sense, have been registered, as usual, in a table of errata, although the corrections for most of them are generally obvious from the context. As other errors will doubtless be observed, the author requests, as a particular favor, that they may be promptly communicated to him.

If it does not excuse, it may account for, some inadvertencies, when it is known, that an arduous and responsible work was written and printed, under the unremitting pressure of absorbing and often conflicting duties. Life is flying fast away, while, in the hope of discharging more perfectly our obligations to our fellow men, we wait in vain, for continued seasons of leisure and repose, in which we may refresh and brighten our faculties, and perfect our knowledge. After we are once engaged in the full career of duty, such seasons never come; our powers and our time are placed in incessant requisition; there is no discharge in our warfare; and we must fight our battles, not in the circumstances and position which we would have chosen, but in those that are forced upon us, by imperious necessity.

Yale College, 1830.

CONTENTS OF VOLUME I.

Page.
PLAN OF THE WORK, - - - - - - - 1
INTRODUCTION, - - - - - - - - 7

PART I.—IMPONDERABLE AGENTS.

Sec. I.—LIGHT, - - - - - - - - 25
Its materiality—velocity, - - - - - 25
Its refraction, - - - - - - - 26
Solar phosphori, - - - - - - 29
Its chemical agency, - - - - - 31
" action on animals and vegetables, - - - 32
" " " mineral bodies, - - - - 33
" connection with magnetism—sources of light—Leslie's Photometer, - - - - - 34
Sec. II.—HEAT OR CALORIC, - - - - - - 35
General nature, - - - - - - "
Conclusions, - - - - - - - 42
Effects, - - - - - - - - 44
1. Expansion, - - - - - - - "
Thermometers, - - - - - - 54
2. Distribution of Temperature, - - - - 63
Conduction—Radiation, - - - - - 65
3. Congelation and Liquefaction, - - - - 82
4. Vaporization and Gasification, - - - - 84
Steam Engines, - - - - - - 92
5. Spontaneous evaporation, - - - - - 104
Effects—cold, &c. - - - - - - 105
Wollaston's cryophorus, - - - - 116
6. Ignition or Incandescence, - - - - 117
7. Capacity for Heat—Specific Heat, - - - 119
8. Combustion, - - - - - - - 126
Sec. III.—APPENDIX TO CALORIC—SOURCES OF HEAT AND COLD, - - - - - - 127
Blowpipe, - - - - - - - 128
Table of freezing mixtures, - - - - 136
Sec. IV.—ATTRACTION, - - - - - - - 137
Gravitation, - - - - - - - "
Magnetism—Galvanism, - - - - - 138
Cohesion and Aggregation, - - - - - 139
Crystallization, - - - - - - - 141
Chemical Attraction or Affinity, - - - 151
Definite proportions, - - - - - 160

Page.
Chemical equivalents, - - - - - 164
Appendix to Attraction, - - - - 172
Rules of Philosophizing, - - - - - 173
Apparatus and Operations, - - - - 174
Specific gravity, method of ascertaining, - - 177
Pneumatic Cisterns, - - - - - 181
Gazometers, - - - - - - 183

PART II.—PONDERABLE BODIES.

Sec. I.—OXYGEN, - - - - - - 185
Action on Combustibles, - - - - - 187
Relation to animal life, - - - - 190
Sec. II.—NITROGEN OR AZOTE, - - - - - 193
Atmosphere, - - - - - - 195
Sec. III.—HYDROGEN, - - - - - - 201
Properties, &c. - - - - - - 202
Water—synthesis, - - - - - - 207
" analysis, - - - - - - 209
" its properties, - - - - - 211
Deutoxide of Hydrogen, - - - - 215
Eudiometry by Hydrogen, - - - - 217
" " spongy Platinum, - - - 221
Hare's Oxy-Hydrogen Blowpipe, - - - - 224

ALKALIES.

Preliminary Remarks and Statement, - - 228
Sec. I.—AMMONIA, - - - - - - - 230
Composition, - - - - - - 233
Sec. II.—POTASSA, - - - - - - - 238
Properties, - - - - - - 240
Uses, &c. - - - - - - - 242
Potassium, - - - - - - 243
Decomposition of Potassa and Soda, - - 244
Properties of Potassium, - - - - 247
Sec. III.—SODA, - - - - - - - 251
Sodium, - - - - - - 253
Sec. IV.—LITHIA, - - - - - - - 257
EARTHS.—Introductory Remarks, - - 259

EARTHS.

I.—LIME, - - - - - - - 261
Calcium, - - - - - - 264
II.—BARYTA, - - - - - - - 267
Barium, - - - - - - 268
III.—STRONTIA, - - - - - - 270
Strontium, - - - - - - 271

Page.
IV.—MAGNESIA, - - - - - - - 272
Magnesium, - - - - - - - 274
V.—SILICA, - - - - - - - - 274
Silicon, - - - - - - - 277
Glass, - - - - - - - - 279
VI.—ALUMINA, - - - - - - - 283
Porcelain and Pottery, - - - - - 286
Aluminium, - - - - - - - 293
VII.—ZIRCONIA, - - - - - - - - 295
Zirconium, - - - - - - - 297
VIII.—GLUCINA, - - - - - - - - 298
Glucinium, - - - - - - - 299
IX.—YTTRIA, - - - - - - - - "
Yttrium, - - - - - - - 301
X.—THORINA—Thorium, - - - - - "

SIMPLE INFLAMMABLE AND ACIDIFIABLE BODIES, (not metallic,) AND THEIR COMBINATIONS WITH THE PRECEDING BODIES.

Sec. I.—HYDROGEN, (see p. 201,) - - - - 302
Sec. II.—SULPHUR, - - - - - - - "
ACIDS.—Preliminary Remarks, - - - - 305
General Properties—their nomenclature, - 307
Sulphuric Acid, - - - - - - - "
Sulphurous " - - - - - - - 313
SALTS.—Introductory Remarks, - - - - 318
Nomenclature, - - - - - 319
Sulphates of Alkalies and Earths, - - 321
Sulphate of Potassa, - - - - - "
Bi-sulphate of do. - - - - - - 323
Sulphate of Soda, - - - - - - 324
" Ammonia, - - - - - - 325
" Lime, - - - - - - 326
" Baryta, - - - - - - 328
" Strontia, - - - - - - 330
" Magnesia, - - - - - - 331
" Alumina and Alum, - - - 334
Sulphites of Alkalies and Earths, - - 337
Sulphite of Lime—of Baryta, - - - - "
" Strontia, Magnesia, Alumina, Potassa, Soda, and Ammonia, - - 338
Hypo-Sulphurous Acid, - - - - 339
Hypo-Sulphites, - - - - - - - "
Hypo-Sulphuric Acid and Hypo-Sulphates, - 340
Sulphuretted Hydrogen, - - - - - 341
Bi-Sulphuretted Do. - - - - - 344

ERRATA—VOL. I.

Page 49, l. 6 fr. top, after *with*, dele *one of*; and after *another*, insert *of the same.*—p. 58, l. 7 fr. bot. dele *or melting snow.*—p. 128, l. 15 fr. bot. for *illustrating*, read *illustrated.*—p. 139, (*g.*) after *chlorine*, read *and bromine.*—p. 148, l. 19 fr. top, after *which*, read *have.*—p. 155, l. 4 fr. top, dele *except the first.*—p. 161, l. 3 and 4 fr. top, for 40, read 78; and for 78, read 40.—p. 162, l. 7 fr. top, for 1, read 2.—p. 168, l. 10 fr. top, after + 0.0694 x 3 =, add 1.1804.—p. 169, l. 27 fr. top, before *acid*, read *oxygen of the.*—p. 180, l. 5 fr. top, for x 18, read + 18.—p. 186, 4(*c.*) before *for*, read *grs.*—p. 201, 2(*a.*) after *muriatic*, read *acid.*—p. 202, 4(*c.*) for 0.694, read .0694; and p. 210, l. 11 fr. bot., 373, l. 5 and 6 fr. bot., 403, (*b.*), 408, l. 9 fr. bot. the dec. point is either misplaced or omitted.—p. 232, (*b.*) for *weight* 18.17 grs., read *weight of 100 cub. in. is*, 18.17 *grs.*—p. 241, l. 15 fr. top, after *of the*, read *ashes of the.*—p. 248, l. 18 fr. top, before *potash*, read *nitrate of.*—p. 262, l. 17 fr. top, after 32° for . *A* read , *a.*—p. 288, l. 10 from bot. before *conical*, read *and.*—p. 297, (r.) (in a few copies,) for *zirconia*, read *zirconium.*—p. 315, (*k.*) for − 31, read + 31.—p. 326, l. 2 fr. top, interchange 1 and 2.—p. 332, (*i.*) dele *carbonate of.*—p. 337, l. 1 fr. bot. for 40, read 32.—p. 338, l. 11 and 12 from bot. for 9 = 108 = 172, read 8 = 72 = 136.—p. 339, l. 16 and 17 fr. top. for 32, read 16 and for 40, read 24.—p. 340, l. 4 fr. bot. for 1, read 2; l. 25 fr. top, for *ous*, read *ic*, and vice versa, p. 426, l. 10.—p. 355, 2 (*a.*) l. 18 fr. top, for *it*, read *charcoal.*—p. 357, l. 20 fr. top, for *oxide* 35, read *acid* 35.—p. 361, (*kk.*) l. 16 fr. top, for *of iron*, read *of lime.*—p. 371, l. 21 fr. top, (p.) for *fluid*, read *ice* and omit the paragraph (*q.*)—p. 383, bot. l. after *once*, read *in.*—p. 392, l. 15 fr. top, interchange 70 and 30.—p. 399, l. 17 fr. top, after *containing*, read *in proportion to the oxygen.*—p. 424, l. 21 fr. top, for *are*, read *is.*—p. 425, bot. dele note marked †.—p. 427, l. 7 fr. top, for *phosphorus*, read *phosphorous.*—p. 489, l. 10 fr. top, interchange 20 and 28.—p. 506, l. 24 from top, after *for*, add *future trial.*—p. 517, l. 21 fr. top, for *selenic*, read *selenious.*

PLAN OF THE WORK.

I. Introductory Remarks, on the general nature and objects of the physical sciences, especially of chemistry, and on its connexion with the other departments of natural knowledge.

II. The Imponderable Agents.

An outline of the great powers which produce, influence and modify chemical phenomena, exhibiting their nature as far as it is understood, and their effects as far as they are ascertained.

They are treated of in the following order—

1. Light,
2. Heat or caloric,
3. Galvanism,
4. Attraction.

Galvanism, including electricity and magnetism, as far as they are chemical agents, is only sketched in a very general way, in the early part of the work: the fuller development is reserved for the conclusion, after all the facts of the science have been explained, and when, as the illustrations are drawn from every part of chemistry, they will of course be best understood.

III. The Ponderable Bodies.

I. Inorganic bodies, including all that do not belong to the animal and vegetable kingdoms.

1. *Oxygen;* one of the bodies that exist in greatest abundance, and whose functions and relations are the most important, is first described; and its properties are continually illustrated in the progress of the work.

I have not thought it best to describe the simple substances in uninterrupted succession. Such a method does not appear to me to present advantages, sufficient to compensate for the inconvenience of plunging, at once, into the most complex parts of the science, which must be done, if we would draw the elementary bodies from their combinations, and present them, in the beginning, in a connected view.

For this reason, chlorine with all its complex relations, and difficult theoretical points, is reserved until the student has become familiar with numerous important chemical facts, and until those substances by whose aid it must be obtained, have been exhibited. It is then easy to revert both to the simple and compound bodies that have preceded, and to explain the relations of chlorine to them; and the similarity between chlorine and oxygen, as supporters of combustion, can then be made even more intelligible, than in the outset.

It is obvious, that wherever chlorine may be placed, iodine must follow, because of the great similarity in the properties of the two bodies, and because, alone, iodine would be less intelligible than chlorine. Upon this plan also, the origin of iodine from the marine plants and other natural sources, admits of more intelligible explanation. The new body bromine, from its character and affinities, naturally comes in immediately after chlorine and iodine. It has been the practice, of late years, to rank oxygen, chlorine, and iodine together, because they have similar electrical and chemical relations: and fluorine, a principle which is, as yet, known only in name, has been added to the list. As our evidence of the simplicity of any body is merely negative, it is possible that all the bodies now received as simple, may be hereafter decomposed, and every table of simple bodies must be regarded as an assumption, founded on the negative fact, that those bodies have not yet been decomposed.

The natural process of acquiring knowledge is the analytical, or the progress from the complex to the simple, from the whole to its parts; the shortest is the synthetic, that is, from the simple to the complex; from the parts to the whole; and this is the course now more generally pursued in chemistry. If our knowledge were perfect, this would be not only the most obvious, but the best process; and perhaps that mode will be found to combine most advantages which unites them both. With this view, I have, therefore sometimes adopted the one and sometimes the other, aiming to present the most important elements and combinations as early as possible.

The atmosphere and water are concerned in nearly all chemical phenomena.

2. I have therefore introduced, after oxygen, an account of *nitrogen*, and then, at the next step, the composition and leading mechanical properties of the atmosphere.

3. Then follows *hydrogen*, with the composition and properties of water; and as a natural appendage, the compound or oxy-hydrogen blowpipe. We are thus early put in possession of this useful and splendid instrument.*

4. *The alkalies and acids* are among the most important of the chemical agents, and it is necessary that their properties should be

---

* This instrument is in my laboratory, kept in readiness, and is used as occasions require, through the whole course.

understood as early as possible. It is perhaps not quite obvious which should be first presented to the student. Here, however, as well as in every other arrangement, it is as desirable, as it is difficult, to avoid anticipation: begin where we may, something must be brought into view that has not been explained; the only proper course is, to anticipate as little as possible, and when it is unavoidable, to give, at the moment, the explanation necessary to render the step intelligible; or to refer to the proper source whence it may be obtained. In *teaching*, I have, with respect to the priority of acids and alkalies, tried both methods, and have concluded, that the alkalies are presented first, with most advantage. The earths, of course, follow in the train of the alkalies.

I have not thought it advantageous to break up the natural classes of alkalies and earths, and place them among the metallic oxides.* Strict logic would justify, perhaps require such a method; but the convenience of teaching and learning, is in my view, decidedly against it; and there is in fact, no more difficulty in learning the properties of potassium and sodium under potassa and soda, than of the latter under the former. Still, when the list of the metals is given, these two metals and others of a similar character can be included, and a proper reference can be made to the places where the description of them will be found.†

In teaching, the great object should be, *to find our way into the mind of the pupil, and to fix there, the knowledge that we present* to him. He is, ordinarily, no judge of our theoretical views with regard to classification and arrangement; he will, in most cases, even fail to understand us, when we discuss them; and he will be best satisfied, with that course which, in the most interesting and intelligible manner, presents to him the greatest amount of useful knowledge.—Both in my public courses of lectures, and in the present work, I have therefore, considered this object as paramount in importance to every other.

5. *The simple, non-metallic combustible bodies* are next introduced, both because their history is remarkably interesting and instructive, and because they are the bases of the most important acids, whose history is easily and naturally developed, in connexion with that of these combustibles. Hydrogen, already described along with water, comes again into view as the basis of muriatic acid. Nitrogen,‡ although, in a popular sense, strictly a non-combustible;

---

* Since the metallic oxides include bodies of such widely different properties, I can see no impropriety in distributing them into classes. I am supported in this arrangement by the late edition of Murray.

† The new *vegetable* alkaline principles are so peculiar in most of their properties, that there would be no advantage in classing them with the alkalies commonly so called.

‡ Also before described in connexion with the history of the atmosphere.

still, because it possesses affinities, and produces in combination, results entirely similar to those of the combustibles, is thrown into the same class, for the purpose of bringing forward the important acids and oxides of which it is the basis.

Two of the least important of the simple combustibles, boron and selenium, are reserved until this period: their history bears no very important relation to that of most of the other bodies, but, as they too form acids, they are disposed of in the train of the other combustibles, and of the great agents that sustain combustion.

Fluoric acid, which although undecomposed, has without doubt, a combustible base, is naturally assigned to the same place, in the classification, and from its combining, in an interesting manner, with boron, it comes immediately after that body, and before selenium, whose character is rather anomalous, but more allied perhaps to the combustibles than to the metals, where many have placed it.

6. *Chlorine and Iodine and Bromine* are introduced after the elementary non-metallic combustibles have been described, and at a period when, as already intimated, their history becomes intelligible.

The history of bodies, thus far described, embraces a great part of the philosophy of chemistry, and no small part of the most important facts of the science. If we were to name any portion of chemistry, that is more splendid in its experiments, and more affluent in important results, than another, it would be that which is included in the history of the elementary combustible bodies, especially when we add their relation to chlorine and iodine, which follow immediately after the simple inflammables.

7. The metals come next, and their history includes all the remaining elementary bodies. There is a general agreement among authors, as to the place which most of the metals are to occupy in a systematic arrangement, and no one at present thinks of presenting them, as some formerly did, in the beginning, along with other elementary bodies. It is true that some of them are used in the demonstrations that precede, but as most of the facts are familiar, and the phenomena intelligible, this creates no difficulty; every one can understand, for instance, how iron decomposes water, and he will comprehend how sulphuric acid aids in that process, just as well before as after he has studied the properties of iron and of the other metals.

II. Organic Bodies.

They owe their particular modes of existence, to the joint action of the laws of life and of matter.

There is, of course, nothing elementary in this part of the subject. Both animals and plants must derive their elements from the unorganized kingdom; and, in relation to them, our most interesting task is, to trace the various proximate principles, in which the elements are combined. This part of chemistry is less splendid than the preceding; but it is fruitful in important information, and much of it is applicable to common wants and occurrences.

1. *Vegetable Bodies.*

We have here only oxygen, carbon, and hydrogen, as essential to the constitution of most plants; nitrogen is found in some, and the number containing it is greater than was formerly supposed; but the proximate principles are numerous and important, and the student is astonished to find, that such diversified results are obtained from the union, in different modes and proportions, of three or four elements.

2. *Animal Bodies.*

The few remarks, just made, are applicable here with some qualifications.

The same elements are found as in vegetables; and nitrogen, instead of being an occasional, is nearly a constant principle. The number of proximate principles is however more limited than in the vegetable kingdom, but their history is instructive and important.

All are agreed in giving a late place to the chemistry of organized bodies; for it is obvious, that it would not be intelligible at an earlier period.

GALVANISM.

It has been already stated, that this power, although mentioned and described, generally, among the imponderable agents, is better understood, after the student has been made acquainted with all the other facts in chemistry.

As a general power, its most important function is, in the decomposition of bodies, ending in the transfer of their elements and principles, to its respective poles. This being, in the begining, explained, and experimentally proved, in connexion with the history of the other imponderable agents, there is no difficulty in marking and understanding the polarity of each body as we proceed, and when we come to present Galvanism, in form and in fulness, at the end of the course, this general arrangement of both elements and proximate principles can be recapitulated, and experimentally illustrated in detail, with great advantage.

Neither is there any thing in the earlier parts of the course that renders it necessary to exhibit the deflagrations, ignition,* and muscular shocks produced by this agent; and which, when presented at the conclusion, with the aid of powerful apparatus, terminate a long course of demonstrations and reasoning, with the most brilliant finish that can be desired.

So far as the natural history of bodies, and their analysis, and applications to use are proper subjects of attention in a concise Manual, I have thought it better, in general, to give the facts, in connexion with the different articles to which they belong, rather than at the end of the work.

The numerical tables that are not given in the body of the work, are of course contained in an appendix. They are necessarily selected from different authors, and although little used by the student of mere elements, are important for occasional reference.

---

* Dr. Hare however uses a small calorimotor to explode gases; and his larger instruments exhibit results, more splendid and interesting, than any other Galvanic apparatus with which I am acquainted.

INTRODUCTION.*

I. PHENOMENA AND SCIENCES CONNECTED WITH NATURAL OBJECTS.—As man is, necessarily and constantly, conversant with natural objects, he cannot, if he would, be wholly withdrawn from *the physical phenomena*, which are perpetually exhibiting the relations of material things.

In ancient times, every thing relating to natural bodies was included under PHYSICS, and this term therefore, comprised NATURAL HISTORY, NATURAL PHILOSOPHY, and CHEMISTRY. Since the more extended cultivation of natural science, and particularly since the time of Bacon and Newton, the external appearances† of natural bodies have been included under NATURAL HISTORY, and their analysis and composition are assigned to CHEMISTRY.

1. NATURAL PHILOSOPHY occupies itself with the general affections and mechanical laws of bodies, with the physical‡ laws of light, heat, magnetism and electricity, and in short, with all that is not included in the two other great divisions of natural science. It is a science of high importance; it is in every university, a regular branch of education, and in every enlightened country, an object of diligent cultivation. It is founded on observation and experiment, and the application of the mathematics, in aid of its researches, has given them both dignity and certainty.

The mathematics are applied to most of the physical sciences, not excepting Chemistry.

They are founded on intuitive truths, and embrace the relations of magnitude and number. In these relations, every one is interested, and were there no other use in mathematics than to supply us with precise ideas and terms, for the forms of external things, and with correct expressions for the distances and positions of objects, they would relieve us from much obscurity and confusion. The study of the mathematics, greatly invigorates and sharpens the understanding, by establishing habits of patient investigation, of exact method, and close reasoning, besides conducting us also to many important practical results. The mensuration of heights and distances, the computations of quantity, both superficial and solid, and the linear and angular measurements of perspective, and of navigation, surveying and astronomy, are among its most familiar and obvious applications.

---

* Revised and abridged from an introductory lecture of the author, published in October, 1828.

† In part also under Natural Philosophy.

‡ As distinguished from the chemical laws.

To return to Natural Philosophy, the student in this science learns, with pleasure and surprise, that the same power which retains Jupiter in his orbit, precipitates a falling drop; that a feather, a balloon and a ship of the line are floated by statical pressure; that the same power causes a narrow column of water, sustained in a tube, to raise a weight, many thousand times greater than its own; that by its means a cascade falls through the atmosphere, which in its turn, raises a column of water in a pump; and that gravity exerts an uninterrupted dominion over atoms, planets and systems. It is seen also by the learner, that the mechanical powers, so indispensable to our existence and efficiency, and that the motions of animals are dependent upon similar principles, and gravity is not unfrequently the immediate agent.

The phenomena of LIGHT are among the most beautiful and instructive of those belonging to Natural Philosophy. The rainbow is a splendid example of the decomposition of the solar beam, effected by the refractive power of the drops of water; still, magnificent and beautiful as it is, it excites perhaps less astonishment in the beholder, than the colors exhibited by the common prism in a darkened room, where the iris, although very small, compared with the bow, is more intense, and is brought within our more immediate view. The astonishing results produced by the solar focus, in which the concentrated beams melt and dissipate metals and stones; the surprising and beautiful effects of the common, the lucernal, and the solar microscope, in whose fields of vision motes become beams, and animalculæ rival the gigantic animals; the wonderful illustrations of the eye, on whose retina, either uncovered by dissection, or imitated by art, are seen painted distinctly, in all their varieties of color and of form, the fields, the groves, the sky, the faces of men, and all the objects that surround us; the power of the telescope, by which we penetrate into the awful darkness of space, and look through the veil that covers the heavenly bodies; these are a few of the wonders which natural philosophy teaches respecting light, that incomprehensible emanation, without which the creation would become cheerless and desolate, and animated beings would dwindle and die.

THE ATMOSPHERE, in tranquillity, is little regarded except as affording the means of comfortable respiration to the whole animal world; but, disturbed in its statical pressure, by the influence of heat, it generates not only land and sea breezes, monsoons, and trade winds, but the hurricane and the tornado. Navies are overwhelmed in the waves; the oak and the cedar are prostrated; and man and his works, his towers of strength, and his pinnacles of pride are level-led with the dust. The same atmosphere, although invariably the residence of the electric fluid, exhibits, only occasionally, decisive proof of an energy, which pervades the material world. Excited by causes, which, except in their proximate operation, are unknown to us, the electric fluid fills the atmosphere with thunder and lightning. It was reserved for Dr. Franklin to prove, that lightning is identical with the sparks which are obtained by friction from glass or resin, or from dry fur, from our apparel of silk or woollen, and from many other sources. In short, we now know that all things are full of the electrical influence; that we can bring it down from the clouds by kites, metallic rods and wires; that we can evolve it by our machines of glass and metals, and that by the power called Galvanism, using certain arrangements of metals, acids, and other substances, we can produce it at pleasure, connected more or less with the other imponderable fluids, in entire independence of the weather, and of the state of the atmosphere; and at the same time we can render sensible the attraction and repulsion, which are inseparable from its excitement.

Although the experiments, exhibiting these facts, are sufficiently curious, the importance of the subject has, only within a few years, been perceived in its full extent; for it is now believed, that the particles of matter are constantly under the influence of these attractions and repulsions, and that they are producing, without cessation, decompositions and new arrangements.

Associated, every where, with electricity, HEAT both modifies its effects, and produces peculiar phenomena. The mild radiations of the sun, and the gentle fluctuations of temperature are subjects of common experience, and excite no particular surprise. But the amazing energy of VOLCANIC ACTION, far surpasses every other example of natural heat. Science is now in a condition to reason, with considerable probability, as to the causes of volcanic heat, and still more, regarding those of the accompanying phenomena of earthquakes: but leaving these for the present out of view, our attention is arrested by the grandeur of the events, associated with volcanic agency.

The convulsion of the ground, not only in the immediate vicinity, but often in distant countries; the subterranean noises, like internal thunder, and the grating sound produced by the rending of the solid strata; the violent emission of gases, steam, ashes, sand, ignited stones and rocks, and eventually of the current of lava, which flows in a stream of fire down the mountain, and over the nether country; the overthrow of the structures of man, or their inhumation beneath the lava and ashes; the lightning and thunder, in and above the crater; the violent flux and reflux of the tides and the strong agitation of the sea, alternately inundating and draining the adjacent shores; the deluging torrents of rain and mud, and the delusive periods of repose, between the eruptions, sometimes extending to years, and centuries, are among the principal circumstances which characterise volcanos.

ATTRACTION AND REPULSION, although less obvious than some of those phenomena that have been mentioned, are undoubtedly, more important in relation to the system of things, than any or all other natural causes and events.

Gravitation is the bond which connects, equally, the greatest and the minutest parts of our system. Every particle of matter gravitates towards every other; every mass, however large, is attracted by every particle; every member of our system, and every system, in the great system of systems is affected, reciprocally, by every other: projectile power, or immense distance and counterbalancing attractions keep them from rushing together in ruinous collision; and the whole creation of matter is afloat in space, suspended and sustained by the energy of almighty power.

It would be foreign to our present purpose, to designate the details of the various kinds of attraction—the gravitating, the electrical, the cohesive, the chemical, and the magnetic.

The magnetic is universally known, and by its aid we traverse the ocean and pathless deserts. It presents the most striking and familiar example of repulsion, a power, which, springing from various causes, and operating under various forms, is, although unseen, every where active around us. We do not certainly know, that magnetism can be permanently attached to any other substances than iron and nickel,* although we can no longer entertain a doubt, that it holds a permanent connexion with heat, light and electricity.

Attraction is only a name for an unknown cause, of which we have no other knowledge than that it depends on the will of God. Mysterious indeed it is, but it is not more so than the connexion of our intelligent minds with our living bodies. The Creator can endue matter with any properties, and there are, undoubtedly, many possible qualities, which he has not bestowed, and many actual ones, which we have not discovered.

ASTRONOMY examines the heavenly bodies, and the construction and relations of the celestial systems. It has taught us that the diffuse light of the Galaxy is composed of the mingled effulgence of innumerable stars, each of which is, probably, the centre of a system, and the continually increasing power of *penetrating into space*, acquired by the modern improvements of the telescope, evinces, that we have only begun to number the stars, and that we shall never be able to call them all by their names. But we have measured the distances and the dimensions of the planets and the periods and the rapidity of their revolutions; and we have ascertained their absolute and relative weight. We know not where discovery will stop; the noble science of astronomy is now cultivated with an ardor not surpassed even by that of the age of Newton, and with means far superior. Innumerable discoveries of new stars have been made; and it is ascertained, that a part of the fixed stars have a revolution indicating the movements of the members of particular systems. This is true, especially of what are called the double stars, and the sublime conception is entertained, that the whole stellary system, with its myriads of planetary worlds, revolves in the course of ages around a common centre.

---

* Some add cobalt.

Astronomy is, not without reason, regarded, by mankind, as the sublimest of the natural sciences. Its objects, so frequently visible, and therefore familiar, being always remote and inaccessible, do not lose their dignity.

Although Newton, a century ago, unfolded the structure of the universe; Herschel, La Place, La Lande, and other distinguished astronomers have continued to enlarge our knowledge of the heavens* and the Astronomical Society of London diligently collects and compares all discoveries, while some of its members are ardently engaged in making new observations.

The practical applications of astronomy, in determining the latitude and longitude especially at sea, are highly important; the exact calculation and prediction of some of its more striking phenomena have removed the superstitious dread of eclipses, and substituted a rational comprehension of their cause; while the transits of the planets and the measurement of arcs of great circles of the heavens in different latitudes, have been thought sufficiently important to justify voyages and journeys to the most distant and inhospitable regions. It may be mentioned also, without impropriety, that the observation of the heavenly bodies is a rational source of amusement. In a fine night, the telescope, although not like that of Herschel, of immoderate size and expense, is an interesting companion, and we contemplate with delight the mild lustre of the evening star, the fiery face of Mars, the silver orb of Jupiter, his belts and his satellites, and the incomprehensible rings of Saturn.†

---

* Chalmers, with his own peculiar eloquence, has arrayed astronomy in new attractions, by connecting its physical features with our moral instruction.

† In this connexion we ought not to forget Dollond, Lerebours, Fraunhofer and other distinguished artists without whose aid the science of astronomy must have been arrested in its course.

2. **Natural history** describes the external appearance or at least the distinctive characters of all natural bodies. Its numerous sub-divisions, are all included under Zoology, Mineralogy and Botany.

Zoology, which includes the whole animal world, comprehends also a great number of subdivisions, e. g. ornithology, ichthyology, herpetology, entomology, conchology, &c. As it is conversant about animated beings, it inquires also into their habits, their food, their reproduction, their decay and their death. Strictly, man is at the head of this department of Natural History. Zoology begins with man and ends with the snail and the oyster; and in its course it embraces the elephant and the mouse, the lion and the mole, the whale and the minim, the eagle and the gnat.

Among gigantic animals, the whale, the larger seals, the rhinoceros, the hippopotamus, the wild buffalo, the giraffe, the camel and the elephant, are signal examples, and among the reptilia, the boa constrictor and the anaconda are sometimes of enormous size. In zoology, living animals are of course more interesting and more instructive subjects of study than dead ones, however well preserved.

A menagerie, is one of the most gratifying kinds of museums, and these exhibitions, as regards especially the larger and more perfect wild animals, afford very fine opportunities for the study of zoology. The panthers and the elks of America, the rein deer of Lapland, the lions, the camelopards and the zebras of Africa, and the royal tigers, the hyenas and the elephants of Asia, torn from their native forests and dens, are imprisoned not only in the apartments of Exeter 'Change, of the Tower of London, and of the Garden of Plants of Paris, but in the cages of the travelling caravans which have now become common in this country.

But, where all opportunities from museums, whether of dead or living animals, are wanting, zoology may still be studied, with good advantage, by the aid of the numerous works on this science, illustrated as most of them are by accurate engravings.

Mineralogy and geology comprise all that relates to the mineral constitution of our planet, including its atmosphere and various gases, as well as its waters, its metals, its salts, its combustibles, and its earthy combinations. The study embraces not only mountains and continents, but the pebbles under our feet, the sand on the shores and the dust that is borne on the winds. It attempts to account for the origin and causes of the present state of things, and it contemplates the impending changes, decay and dissolution of the firm substratum of our globe. Minerals, although to some extent constantly before us, are, for the greater part, far more inaccessible than vegetables and animals. Many of them are drawn from the recesses of the earth, from the caverns and mines remote from the light of day.—In this department then, although something may be done with the aid of such things as we can every where obtain, still, a cabinet or museum is peculiarly necessary, and as this study is acknowledged to be both important and interesting, collections in mineralogy are found in colleges and universities more generally than any other subjects of natural history. They have the very important advantage of being, with few exceptions, not liable to destruction, nor to any spontaneous changes. They need no preparation, but when detached from their native situations, and reduced to a proper size, are ready for the museum. This department of nature affords much of the wealth of nations, many of the comforts of civilized and polished society, nearly all the instruments of physical and philosophical research, and most of those of the ornamental and useful arts. Civilization, social refinement and science cannot exist where the mineral kingdom is not explored and understood, and especially where iron and some of the other metals are not known and used.

Although no aliment for living beings is obtained from this kingdom, very important remedies are derived from it, especially from several of the earths and metals. Plants and animals are probably more attractive to the eyes of most persons than the greater part of minerals; still, among crystals are found objects of extreme beauty, whose polish and whose form rival the finest works of art, and some of the gems have ever been selected to adorn diadems and crowns.

Geology, which reveals to us the actual structure of the globe, and the natural position, relation and associations of its productions, affords important light in the research for useful minerals; and it exhibits, in the arrangement and contrivance of the mineral strata, decisive proofs of the power, wisdom and design of its author.

Botany is the natural history of plants. It is a beautiful and eminently useful branch of knowledge. It is constantly extending its researches and adding new species to the great number,* which have been already discovered.

The loftiest forest tree and the humblest shrub are equally within its domain, and every climate, and every continent and island, are visited for the discovery of new species. The plants that grow in mountains indicate, with great accuracy, the climates that belong to the different elevations; the plants and fruits of tropical regions may grow at the foot, and the stunted evergreens of the polar circle may crown the summit.

In this elegant department of knowledge, a sufficient number of its subjects is scattered every where around us, to afford the means of comprehending the outlines of the science and of prosecuting it with considerable advantage. Its dried specimens are preserved with incomparably more ease than those of animals, and it is thought to be an object worthy even of princely munificence to found collections of living plants, and to preserve them in the Botanical Gardens, as is seen in the Royal establishment of Kew in England, and of the Garden of Plants in Paris. Even public spirited individuals* have, either by their own efforts, or by the assistance of private citizens, like themselves, formed botanical gardens, of signal beauty and utility; presenting in one grand perspective, the vegetable glories of the world. The study of the science is thus facilitated, in a surprising degree, and the botanical student finds, within the bounds of at most a few acres, the plants, to have seen which, in their native soils, would have demanded a life of adventure. The vegetable kingdom affords most of the food of men and animals, many medicines, and many materials for the arts.

---

* Fifty-six thousand, or more.

3. CHEMISTRY.—The remaining branch of science relating to natural bodies, begins where Natural Philosophy and Natural History stop. As the gleanings of its early history may be found in the prefaces of the larger elementary works on chemistry, we shall here omit the vague annals of its infancy, and the delusions of its middle age.

It would exceed our limits to trace the progress of chemistry from age to age; to unfold the delusions of ALCHEMY, whose object was to discover the philosopher's stone, an imaginary substance, which, it was supposed, would convert the baser metals into gold and silver; or, to speak of the equally delusive pursuit, after the GRAND CATHOLICON, or universal remedy, which was to remove every disease; to avert death, and confer terrestrial immortality upon man; or to mention the imaginary ALCAHEST, or universal solvent, whose power it was supposed nothing could resist. The alchemist indeed imagined, that these miraculous virtues resided in one and the same substance, and during the dark ages, most of the cultivators of what was then called chemistry, smitten with the delirium of alchemy, pursued their occult processes, in cells and caverns, remote from the light of heaven, and wasted their days and nights, their talents and their fortunes, in a vain pursuit. The alchemist however accumulated many valuable facts, which have been employed, with good advantage, in laying the foundations of modern chemical science.

Some knowledge of chemical arts is coeval with the earliest stages of human society, and it has happened with this, as with other branches of natural knowledge, that many facts were discovered, and accumulated, in the practice of the arts, and in domestic economy, long before any general truths were established, by a course of inductive reasoning, upon the phenomena.

---

* As was done by Mr. Roscoe and Dr. Currie of Liverpool, Dr. Hope of Edinburgh, Mr. Bartram of Philadelphia, and Dr. Hosack of New York.

The arts are all either mechanical or chemical, and not unfrequently both are involved in the same processes. The practices of the arts may be regarded as experiments in natural philosophy and chemistry. The object of the artist is usually gain; but he, or any other person, who views the facts correctly, may reason upon them advantageously, and thus obtain important instruction.

Glass is a chemical compound, usually of siliceous earth and fixed alkali, or in a more extended view, of alkaline, saline, metallic and earthy materials. These, after being duly proportioned, are combined by the effect of fire, and various adventitious matters are added, to impart color or to discharge it, to increase the density, or to diminish the hardness, or for various other purposes.

The production of the materials of the glass depends therefore upon chemical principles, and is thus far, a chemical art. But, the fabrication of the vessels depends upon mechanical causes, principally the breath of the artist, injected through an iron tube, to which the melted glass is made to adhere. The subsequent cutting, grinding, and polishing of the glass are also mechanical, and thus glass is a production both of chemistry and mechanism.

Soap, (except the mere act of mingling the oil and the alkali,) is a production of chemistry alone; a watch is a result of mechanism, but the metals of which it is made are prepared by chemistry and mechanism united; wool is carded, spun, woven, fulled and sheared by mechanical means, but it is scoured and dyed by chemical processes, and thus through a multitude of instances, the purposes of society are accomplished, by the application of the principles of one or of the other, or of both of these sciences.

The *science* of chemistry considered as a collection of elementary truths derived from the study of facts, can scarcely be referred to a period much beyond the commencement of the last century, and its principal triumphs have been achieved, since the middle of that period. It would be premature, to detail, on the present occasion, the particular discoveries, which, like stars, rising successively, above the horizon, have broken forth in rapid succession. Those discoveries, their periods and authors will be mentioned, in giving the history of each particular substance. At present, it would not be proper to attempt any thing more than to convey to those to whom the subject may be new, a general conception of the nature, extent and objects of the science of chemistry, reserving the details for the time when they will be both the most intelligible and the most interesting.

DEFINITION.*—CHEMISTRY IS THAT SCIENCE WHICH INVESTIGATES THE COMPOSITION OF ALL BODIES, AND THE LAWS BY WHICH IT IS GOVERNED.

Remark.—This, of course, includes every possible combination and decomposition.

Chemistry, taking into view the properties discovered by Natural Philosophy, begins its appropriate work where the sister science stops.

The distinction between chemistry and natural philosophy is illustrated by the familiar examples of

1. *Water,*
2. *The atmosphere,*
3. *Gunpowder.*

Thus, water is composed of the bases of two gases; the air of at least two, and gunpowder of combustible and metallic matter and the ponderable part of gases.

Natural History, Natural Philosophy and *Chemistry* are all necessary to complete the scientific history of any thing.

Natural History explains the external appearance of bodies;
Natural Philosophy the mechanical properties;
Chemistry the constitution.

This general position is easily illustrated by reference to *amber, coal, calc-spar, fossil salt,* and other familiar bodies.

Chemistry is distinguished as *an art* or a collection of arts, from *chemistry* as a science: the former is empirical, the latter is guided by established principles, and they are now, in numerous instances, happily united, in the hands of both practical and scientific men.

Chemical arts are numerous; *glass* and *soap-making*, have been already mentioned, and *pottery, metallurgy,* and *dyeing*, may be added; the latter depends on the affinity of coloring matter for fibre, or for the mordant, or for both.

The vinous fermentation produces cider, wine, perry, bear, metheglin, &c. Carbonic acid gas is evolved, while alcohol is formed, and the rapidity of the process depends on the temperature.

Leather, is formed from skins and tannin contained in the astringent vegetables; the tannin of the latter uniting with the gelatine of the skin.

Bread, is produced by a peculiar fermentation: its sourness, owing to excessive fermentation, is corrected by an alkali and the carbonic acid which is evolved, renders it lighter than before.

---

[*] For various definitions the student may see the principal authors, Thomson, Fourcroy, Henry, Murray, La Grange, Thenard, Davy, Brande, Turner, Hare and others.

Ink; the theory of its formation is, that the astringent principle unites with the oxide of iron, and gum Arabic or sugar suspends the precipitate.

The burning of lime consists in the expulsion of the carbonic acid, by heat; the acid gas forms nearly one half of the weight of the limestone, marble, and chalk.

Art and *science* mutually aid each other, because art furnishes hands and science eyes; science without art is inefficient; art without science is blind.

The philosophical chemist must understand the *principles* of the chemical arts, and the more of the practice he knows the better.

Chemical artists should understand the science, at least of their own arts, and practical knowledge is of course indispensable.

Not satisfied with the knowledge of the external properties and the mechanical relations, which are unfolded by Natural History and by Physics, but taking them into view, and retaining and using their principal discoveries, chemistry proceeds to investigate the hidden constitution of every species of material existence, in earth, sea and air.

Earth, air, fire and water, were the four elements of the ancient school. They have however, yielded to analysis, and water, bland and simple as it seems, contains two bodies, whose properties, are entirely different from its own and from those of each other; burning, when mingled and ignited in large quantities, with violent explosion; and in a small stream, with a heat, which melts and dissipates the firmest substances. We should never have conjectured that water, whose great prerogative it is, to extinguish fire, contains both a combustible and a supporter of combustion.

The air, the pabulum of life to the whole animal and vegetable creation, mild and negative like water, is not *simple* but contains incidentally many bodies,—essentially however only two; one of which and that, constituting four fifths of the whole, is, and was intended to be, in a high degree noxious and even deadly to animal life and fatal to combustion. The air does not destroy life instead of invigorating our frames, and extinguish instead of inflaming combustion, because the prevalent noxious principle of the air (nitrogen) is balanced by a life and fire-sustaining principle (oxygen) too vigorous to be trusted alone, and therefore, diluted exactly to the proper degree, by the opposite principle, both being, by another extraordinary provision, sustained, in constant proportion, and thus producing a salubrious and unchanging atmosphere.

The earth, under our feet, the soil, the sand, the gravel, the firm substance of the rocks, is not simple. In this ancient but assumed element, we have a double complexness. The one imagined, simple earth contains at least nine, and each of these is again complex, containing for one principle, oxygen, the same that exists both in water and in the atmosphere, united to nine or ten varieties of metals or combustibles none of which are known in common life.

He who is acquainted with the wonderful effects of chemical combination, will not think it strange that half the weight of marble is carbonic acid, and that metals, when combined with oxygen, resemble, very exactly, the earthy substances.

Light as well as heat, is contained in common fire, and therefore it is not simple, unless fire and heat are varieties of one and the same thing.

Modern research has proved that, besides light, which in its seven prismatic colors, is contained in the solar beam, there is also, in this emanation, an opake, radiant principle, which accompanying light and heat, neither warms nor illuminates, but acts to decompose certain chemical compounds; that there are opake rays which warm but do not illuminate, and illuminating rays which are cold to the sense of living animals, but impart to the universe its splendid drapery of colors; and that, associated with one or more of these emanations, there is a surprising power, which imparts magnetism to a needle, and gives it the properties of the loadstone. But we have used the word element without defining it.

An element is an undecomposable body—it is therefore simple, or in other words not reducible to any other form of existence. We must however, carefully distinguish, between *real elements*, and those which are such, only in relation to the present state of our knowledge. When modern science speaks of a body as elementary, it intends nothing more, than that it has not been decomposed. It is therefore simple as far as we know, but it is possible that, by future efforts, it may be decomposed. Although we have no reason to doubt, that there are *real* elements, we cannot say, that we are certainly in possession of any one element. It is, however, perfectly safe to reason upon bodies as elementary, until they are proved to be compound. Iron is, as far as we know, a simple body; we cannot as yet, exhibit it in any simpler form; all we can do, is to alter its figure and size, without at all changing its nature. But iron rust, or the scales which fly off, when red hot iron is hammered, are not simple; they consist of iron, combined with oxygen, one of the principles of the atmosphere; we can exhibit these substances in a simpler form; the iron, which they contain can be separated from the aerial principle, and both can be exhibited apart, and thus the proof will be complete; red lead and red precipitate are still better examples, because the former can be partially, and the latter wholly, brought back to the condition of metals, by simply heating them.

The four ancient elements, earth, air, fire and water, were assumed at hazard, because they are so conspicuous and important; the conception was grand but it was wholly erroneous.

Instead of four elements, we have at the present time not less than fifty, nearly four fifths of which are metals; the remainder are chiefly combustibles, and bodies, which, combining with combustibles and metals with peculiar energy, are generally called supporters of combustion.[*]

Our simple bodies then are

1. Metals, about - - -	40[†]
2. Combustibles not metallic, - -	7[†]
3. Principles or supporters of combustion, -	2 or 3
4. One body, or possibly two[‡] of an undetermined character; in all - - - - -	50 or 51

5. Imponderable bodies, light, heat and electricity; besides the power called magnetism and the other varieties of attraction.

The principal object of chemistry is to display first, the great powers upon which its phenomena depend; and secondly, the properties of the elements, the mode and energy of their action, the combinations which they are capable of forming, the properties of the resulting compounds, and the laws by which they are governed. This statement, obviously, includes all bodies natural and artificial. There are many chemical compounds made by art, which, as far as we are informed, do not exist in nature, and there are many natural bodies which art has not yet been able to imitate.

The philosophical chemist studies both the properties of the elements, and the constitution of the intermediate or proximate compounds of the whole material world, as far as it is tangible by man. Of the chemical constitution of the planetary and stellary bodies, we have no knowledge, except from the hints that are afforded by the occasional projection to our earth, of stony masses, severed by explosion from luminous meteors or fire balls, which occasionally pass, with great velocity, through our atmosphere.

It will be easily understood, that the philosophical chemist undertakes an arduous and responsible duty, involving much manual skill and labor and mental effort, but the reward is rich and gratifying.

---

[*] Some object to this phrase, preferring to consider combustion as being only an example of intense chemical action; this view is philosophical; but combustion is so frequent an occurrence and involves so many imporant chemical events, that it is convenient, in accordance with the general practice of mankind, to designate it and the bodies concerned in it, by a peculiar phraseology.

[†] It is perhaps doubtful where some of these bodies ought to be classed—whether among metals, or combustibles.

[‡] Perhaps silicon and bromine; we have however classed them where they appear to belong.

The veil is withdrawn from the face of nature, and a constitution of things, not at all suspected by those ignorant of chemistry, is unfolded.

The pupil in this science discovers that he has, all his life, walked unconsciously amidst powerful, although unseen energies; that like a child scattering sparks among gun-powder, he has often been sporting with dangerous elements, and that, with all his curiosity and intelligence, he has known only the surface of things. He finds, every where, innumerable applications of his knowledge to purposes of practical utility, to those of domestic life, to the arts which enrich and adorn society, and to the illustration of the wisdom, power and goodness of that great being, whose pleasure called the physical universe into existence and constantly sustains it in order and beauty.

To exhibit the proof of these statements, even in outline, would require a distinct recital, and might well occupy a treatise;—but opportunities will occur in the progress of this work, when these truths may be, to a certain degree, illustrated.

It would be premature, to attempt, at this time, to exhibit the nature of the evidence upon which chemical deductions are founded, and the mode in which the study and exhibition of the science are prosecuted.

It is sufficient to say, that like the other physical sciences, chemistry derives its evidence, from experiment, and the observation of facts; but, as a great proportion of the facts are such as do not occur in common life, and still, as they all have their foundation in the constitution of things, it becomes necessary for the philosophical chemist to perform a great number of experiments; in other words to exhibit numerous facts; for, an experiment is nothing but the exhibition of a fact, happening according to natural laws, which it is not in our power either to create, to cancel or to modify. Hence, the necessity of becoming well acquainted with those laws. Whenever all of them shall be fully understood, then chemistry will have reached its perfection, and in relation to the science, the greatest service which we can perform, is to extend and perfect its general laws. At some future day, it will not be necessary to study facts so much in detail as now; selections will be made to illustrate general principles, and thus chemistry will be assimilated to natural philosophy.

Chemistry may be regarded in three views, all of which are interesting and important.

1. As a branch of general philosophy.
2. As a school for the chemical arts and for many of those of domestic economy.
3. As an important auxiliary to the profession of medicine and to pharmacy.

In accordance with all these views, it is now ardently and perseveringly cultivated, in every enlightened country. In every university and medical school; in every college; in many academies; in voluntary associations, in larger and smaller towns, supporting Lyceums* and Athenæums;* in popular courses of lectures, sustained by private individuals; and even in manufacturing establishments, fostered by the zeal of the operative artizans; chemistry, with the sister sciences, natural philosophy and natural history, is assiduously and advantageously cultivated. It would in this age, be as disreputable for any person, claiming to have received a liberal education, or to possess liberal knowledge, to be ignorant of the great principles and the leading facts of chemical as of mechanical philosophy. Many intelligent artizans now resort to philosophical lecture rooms, to learn more perfectly the principles of their respective arts; and the great familiarity with the practical facts of their callings which they, of course possess, and ordinarily in a degree superior to that attained by teachers of science, enables them to apply with great advantage the general principles which they acquire.

Domestic economy is greatly benefitted by a correct knowledge of the principles of natural science and especially of chemistry. Besides the instances that have been already named—the combustion of fuel; the equal and economical distribution of heat and light; the preservation of delicate fruits and of their extracts or jellies; the preparation of food by steaming, boiling and roasting; the extraction of animal gelatine; the manufacture of starch; the separation of butter and cheese from the milk; the bleaching and dyeing of stuffs and many more domestic arts depend upon the principles of science, and chiefly upon those of chemistry. It is true that these things are accomplished, with more or less skill, by persons unacquainted with science, but they would be better and more effectually done, were the artists enlightened more generally in its principles. To insist on no other instance, there is no doubt that in the common modes of using fuel, a large part is wasted, and that part skilfully applied would be more effectual than the whole, as it is in most cases actually used.

There is now, generally, but one opinion as to the importance of chemical science to the profession of medicine. This opinion is sufficiently evinced by the fact, that there is no medical school in which chemistry is not taught, nor any medical examination in which this topic is omitted. It is true that medicine may be practised, empirically, by those who understand neither the structure of the human frame, nor the nature and properties of the substances, which they administer. But who would choose to trust such men; or those who, equally uninformed, as to the nature of things, mix, compound and vend, by precept and example alone? Both may indeed do it, to a certain extent, successfully, but it is travelling blindfold, and, at the same time, leading others. Medicine and pharmacy both need the aid of scientific chemistry; then they can proceed with intelligence and confidence—they can shun and rectify errors, discard abuses, and add new resources to the healing art. They will avoid mixing inconsistent and mutually subversive ingredients;—they will reject the spurious and inert—scrutinize, with skill and knowledge, the genuineness of medicines, and avoid painful—sometimes fatal mistakes.

---

* Popular names in this country for certain institutions having for their object, the dissemination of useful knowledge.

The principles of natural and experimental philosophy as well as of chemistry, should enter into the education of a medical man; and if he has not been already initiated into these elements, he should neglect no favorable opportunity of acquiring them. They are constantly brought into view, along with the principle of life, in reasoning upon the phenomena of the human frame; and in surgery, a correct knowledge of mechanical principles is of the utmost importance. A knowledge of natural philosophy should every where be—and in some seminaries it is—an indispensable qualification for medical privileges and honors.

The enlightened medical man will regard his profession in a higher view, than as being merely a business, by which he may live. The true physician is a man of extensive scientific acquirements. No other profession demands so much scientific knowledge; and when this is possessed, by a man of powerful and ardent mind, and united to habits of persevering and industrious exertion, the medical man may become entitled to a distinguished rank among philosophers. Probably, science is more indebted to medical men than to those of any other profession. Every young man, who, with competent talents, enters upon the study of this profession, should aim at acquiring enlarged views of general as well as of medical science, and should endeavor to add something to the common stock of knowledge.

The physician, who possesses the true spirit of his profession, will aim at a still higher excellence, that of being a good man. Familiar in the confidence of families, having access to all, in the hour of sorrow, and of tenderness, and weakness, he is, if virtuous and amiable, regarded as the common friend of mankind. It is however in his power, to sow moral contagion, or to diffuse the happiest influence.

In concluding, we may observe for the sake of the general student, that,

Literature adorns and illustrates science, adding much to its attractions, and to the method, perspicuity, and effect of its communications. It cannot be entirely neglected, by any one who would claim an elevated rank in physical science. The accounts of the most valuable researches and discoveries are, to a degree disgraced, by being clothed in a coarse and slovenly style, and communicated without good arrangement, and without logical clearness and precision. It sometimes happens, that able philosophers and mathematicians are accomplished scholars, and then the utmost finish is given to the solid structures of physical science.

No one who has had opportunity to appreciate their attractions, and their utility, can be insensible to the advantages and pleasures of polite literature, and of miscellaneous knowledge presenting as they do, a rich field for investigation, and affording to the student, ample remuneration.

But—*ars longa, vita brevis*, meets us at every turn; and, although the general student, in the regular progress of a university education is of course, made acquainted with the outlines of the principal branches of human knowledge; in after life, we are obliged to say, *non omnes omnia possumus*, while reluctantly giving up the rest, we select and pursue some one art, science, or practical profession.

But our previous efforts are not lost; the *commune vinculum* which connects all the departments of human knowledge, still remains unbroken; the intellect which has been enriched by the elements of science and literature, continues to shed a portion of their lustre over its own particular pursuit, and occasionally to aid, by useful suggestions and partial efforts, those who are travelling upon some other route.

Knowledge is said to be power; it is indeed, power of the most comprehensive and efficient kind.

Knowledge is nothing but the just and full comprehension of the real nature of things, physical, intellectual, and moral; it is co-extensive with the universe of being; reaching back to the dawn of time, and forward to its consummation.

It is inseparable from the incomprehensible existence of the creator, who alone intuitively sees the whole. Human life is sufficient for the acquisition of only a very small part of universal knowledge, and the greatest and the most enlightened mind, measuring its acquirements by this standard, will find no cause for pride.

It is useful when we are about entering on the study of a particular science, and especially of one of so great extent and interest as chemistry, to remember that there are many other interesting and useful branches of knowledge, and that we always assume too much, if we claim all importance and every attraction, for a particular pursuit. This is necessarily the feeling of every one who insulates himself within his own peculiar dominion; but he who takes a comprehensive survey of human knowledge, will learn to appreciate justly his own acquisitions, and to concede to others the favor which he would claim for himself.

* * * * * * *

Probably the greatest step that has been made in chemical science since the discovery of oxygen and chlorine, is in the establishment of the doctrine of definite proportions, depending on the combination of the elements and of the proximate principles in certain fixed ratios,—thus unexpectedly, giving to chemistry a mathematical basis.

PART I. IMPONDERABLE AGENTS.

SEC. I. LIGHT.

"LIGHT IS THE AGENT OF VISION."

The history of its mechanical affections belongs to Optics, but some general facts may be advantageously stated here.

1. ITS MATERIALITY.—By some it is supposed to result from the vibration of *subtile elastic media*; but every thing goes to countenance the idea of its materiality, and this was admitted by Newton.[*] *It cannot be weighed*, because our balances and organs of sense are not sufficiently delicate.

2. ITS VELOCITY *is two hundred thousand*[†] *miles in a second*; it is seven or eight minutes in coming from the sun, and were its weight the million-millionth, or billionth part of a grain, it would, by its impetus, destroy the firmest bodies. Nine millions of particles of that size would not affect our most delicate balances.[‡]—*Thom.*

Momentum, being made up of velocity and quantity of matter, it results, that any degree of momentum may be produced by increasing either the quantity of matter, or the velocity; it therefore follows that the particles of light must be inconceivably small.

3. *Its velocity is progressive*, and has been measured, by observing the eclipses of Jupiter's satellites, when the primary is nearest

---

[*] Dr. Ure has given a different view of this subject.—*Dict. 3d Ed. p.* 563.

[†] One hundred and ninety-five thousand.—*L. U. K.*

[‡] "The materiality of Light is sufficiently proved. Its motion, though inconceivably rapid, is progressive, and may be measured; it may be stopped in its progress, or its direction may be changed; it may be condensed into a smaller, or dispersed over a larger space; it is inflected when passing near to any body, which proves it to be subject to gravitation; it produces chemical changes in many bodies, exists in them in a state of combination, and is disengaged by the exertion of new affinities, when it appears in its original form."

"There is no physical point (says Melville,) in the visible horizon, which does not send rays to every other point; no star in the heavens which does not send light to every other star. The whole horizon is filled with rays from every point in it, and the whole visible universe with a sphere of rays from every star. In short, for any thing we know, there are rays of light joining every two physical points in the universe, and that in contrary directions, except where opake bodies intervene." A ray of light, coming from any of the fixed stars to the human eye, "has to pass, in every part of the intermediate space between the point from which it has been projected, and our solar system, through rays of light flowing in all directions, from every fixed star in the universe; and in reaching this earth, it has passed across the whole ocean of the solar light, and that light which is emitted from the planets, satellites and comets. Yet in this course its progress has not been interrupted."—*Mur.*

to and farthest from the earth. Seven minutes are now allowed by calculation, for the passage of light from the sun to the earth, and one twenty fourth of a second for its passage, from pole to pole, of our earth.—L. U. K.

A body cannot be seen through a bent tube, except by reflection, and the shadows of bodies are exact copies of the form of the original.

4. *It moves in right lines;* never in curves; if turned, it is always at an angle.

5. *Its rays are mutually repellent,* as they always diverge,* if moving uncontrolled; as observed when they are let into a darkened room, through a hole in the shutter—especially when the dust is raised in the room, so as to render the progress of the rays visible.

6. IT OBEYS THE LAWS OF ATTRACTION.

It is refracted in passing from one transparent medium into another; going obliquely from a denser into a rarer medium—the refraction is always from the perpendicular, and vice versa; there is a constant ratio between the sine of the angle of incidence, and that of refraction.

A piece of money being placed in a bowl, and the eye so situated as just to lose sight of it, is rendered visible by pouring in water.

A stick, standing out of transparent water, appears bent at the surface.

A river, or other transparent water, is deeper than it appears to be, because the image of the bottom appears too high.

7. *The amount of refraction is proportioned directly to the density of the body.*

Inflammable bodies refract in a higher ratio, and of course, inflammable gases refract more than those that are not. At 32° Fahr. and pressure 30, the refractive power of the following gases is as follows;

Atmospheric air, - - - - -	1.00000
Carbonic Acid, - - - - - -	1.00476
Azotic Gas, - - - - - -	1.03408
Muriatic Gas, - - - - - -	1.19625
Oxygen Gas, - - - - - -	1.86161
Sub-carburetted hydrogen gas, - -	2.09270
Ammonia, - - - - - -	2.16851
Hydrogen Gas, - - - - - -	6.61436†

In general, the refractive power increases with the density of the body; but inflammable bodies, hydrogen, phosphorus, sulphur, diamond, bees-wax, amber, spirit of turpentine, linseed oil, olive oil, camphor, &c. have a refractive power, from two to seven times greater, in respect to their density, than most other substances.

---

* Rays from the sun and fixed stars, although divergent, are regarded as parallel, because the immense distance renders the angle of divergence indefinitely small.

† Henry, Biot, Arago.

Sir Isaac Newton observed this fact with respect to the diamond, which he thought was probably "an unctuous substance coagulated," thus anticipating the discovery of its inflammability.*—L. U. K.

8. *Light suffers reflection.*

The angles of incidence and reflection are always equal, as is observed in a common plane mirror; when two persons on opposite sides, standing each at the same angle, see each others images.

9. *All objects seen by refraction or reflection appear in the direction of the refracted or reflected ray.*

This is confirmed by constant experience.

10. *Light undergoes polarization.*†

"This name has been given to a property of light, which causes it often to be divided into two portions, one of which is transmitted, the other reflected by the same pane of glass: or one portion sustains refraction in an ordinary degree, the other in an extraordinary degree. Again, all these properties are found to be commutable; so that the portion of the rays which is reflected in one case, may be transmitted in another; or that which in one case sustains the ordinary refraction, in another, may undergo the extraordinary refraction, and vice versa.

These phenomena are ascribed to the different positions assumed by different sets of rays; certain poles, which they are supposed to possess, being variously directed at different times, so as to determine their reflection, or transmission, or the degree of their refraction."‡ This topic belongs to optics.§

11. *Light produces little or no heat.*

The Lunar focus has always been said to exhibit no heat that can be indicated by the most delicate thermometer; and that whether the rays were collected by a lens or mirror. No heat was felt in the pupil of Sir Joseph Banks' eye, from the lunar rays collected by Parker's great burning lens.

But Dr. Howard, of Baltimore, by using his very delicate differential thermometer, filled with etherial vapor,‖ apparently found a little heat in the moon's rays.

The lunar light is composed of all the seven colors, as is evident in the lunar bow, and in the lunar circles.¶

---

* Dr. Brewster states that realgar, (red sulphuret of arsenic,) and chromate of lead, exceed the diamond in refractive power, and all other substances in dispersive power.—*Ph. Tr.* 1813.

† For an account of this curious property of light, the reader is referred to Henry's Chemistry, 10th Edit. Vol. I. p. 154.—Also Edin. Enc. Article Optics.—Nich. Jour. Vol. XXIII, p. 384, and 94th Vol. of the Annales de Chimie, Ure's Dict. 3d Edit. 568, and Cambridge Course of Mathematics.

‡ Hare's Comp.

§ All transparent crystals polarize light, except those whose primary form is the cube or regular octohedron. Iceland crystal (rhomboidal calc-spar) is by far the most energetic.

‖ Am. Jour. Vol. II. p. 329.

¶ Am. Jour. Vol. XIV, p. 397.

12. *Light is not simple.*—It is composed of seven colors, as separated by the triangular glass prism, in the following order.

$$\overbrace{\begin{array}{ccccccc}\textit{Red,} & \textit{Orange,} & \textit{Yellow,} & \textit{Green,} & \textit{Blue,} & \textit{Indigo,} & \textit{Violet.}^{*} \\ 45 & 27 & 48 & 60 & & 40 & 80\end{array}}^{300}$$

beginning with the least, and ending with the most refrangible.

"Dr. Wollaston found that when a beam of light only one twentieth of an inch broad is received by the eye, at the distance of ten feet, through a clear prism of flint glass, only four colors are seen, viz: red, yellowish green, blue, and violet. The different rays being again collected by a lens into a focus, produced uncolored light."—*H.*

13. LIGHT IS CONTAINED IN ALL BODIES.

It appears to be both inherent in them, and to enter them from without.

(*a.*) *It passes through some without any sensible obstruction*—they are therefore transparent, as glass, air, rock crystal, &c.

Other bodies partially arrest the light, and others still allow a little to pass, while some stop it entirely; this gives origin to the terms, transparent, semi-transparent, translucent, and opake.

Strictly, no visible body is transparent, and therefore aerial bodies are really the only ones that are perfectly transparent,[†] and even they, become in a degree visible, in consequence of the disturbed refraction of light.

(*b.*) *Diversity of color is produced by the absorption of some rays and the reflection of others.*

White bodies reflect all, and black absorb all, or nearly all, without decomposition; when a body appears red, green, yellow, blue, &c. all other rays are absorbed and these are reflected. All persons do not perceive colors—we may very possibly find one such person, or more, in every considerable assembly, and many such instances might be collected. Harris, a shoemaker at Allonby in England, could distinguish only black and white; when a child, he could not distinguish the cherries on a tree from the leaves, except by their form and size. Mr. Scott could not distinguish green. Pink and pale blue appeared alike, and so did red and full green—which he thought a good match; several of the relations had similar defects.[‡] A tailor repaired a black silk and a blue coat with crimson.[‡]

---

[*] Quoted from Henry, 10th Edit. Vol. I. p. 156.—Blue is not mentioned in assigning the relative spaces, although it is mentioned in the list of colors; other authors assign 60 to blue, dividing the whole spectrum into 360.

[†] Except chlorine, and one or two others.

[‡] Ph. Tr. 1777, and 78, and 80.—L. U. K. A gentleman of my acquaintance bought and wore a scarlet dress supposing it to be drab; still he was a good judge of pictures. I have known several such examples.

14. *Light is emitted as well as absorbed by bodies.*—Bodies that emit light are called phosphorescent; heat does not accompany this luminous emission.

(*a.*) *Solar phosphori are those which after exposure to the sun, for some time, emit light in the dark.*—Du Fay having exposed a diamond to the sun and immediately covered it with black wax, it shone in the dark at the end of several months, when the wax was removed.

"In 1663, Mr. Boyle observed that the diamond when slightly heated, rubbed, or compressed, emitted a light almost equal to that of the glow worm."—*Ure.*

Snow has been supposed to be a natural solar phosphorus, but this appears to be incorrect; for it does not shine in a perfectly dark place; it seems to operate merely by reflecting the light which is abroad even in the night, except when the clouds are very heavy, in the absence of the moon.

(*b.*) *There are artificial solar phosphori.*

Canton's preparation.—Sulphuret of lime, made by stratifying burnt oyster shells and flowers of sulphur, and heating them in a phial, or in a crucible in a furnace.

Bolognian phosphorus, viz, sulphate of barytes partially decomposed into a sulphuret by ignition, with flour, sugar, gum arabic, starch, &c.

Baldwin's phosphorus is fused muriate of lime. Homberg's depends on combustion. (See alum.)

Herring, mackarel, (or other marine fish,) being put into a phial with water and about one eighth of its weight of common, Epsom, or Glauber's salt, and conveyed into a dark place; a luminous ring is seen after three days, and the whole fluid appears luminous when agitated.*

The phosphorescence of fish when hung up in a chimney corner, and of rotten wood, &c. is probably owing to decomposition preceding putrefaction. Peat earth is phosphorescent.

Canton's preparation and other solar phosphori, on being exposed to the light, shine in the dark, so that we may tell the hour by a watch, and when they cease to shine, they again acquire the power by a new exposure.

(*c.*) *Some bodies become phosphorescent by heat.*—Fluor spar, phosphate of lime, many varieties of feldspar, and many lime stones are of this class. It is usual to pulverize them coarsely, and to throw them upon a red hot shovel in a dark place. The fluor spar from Monroe, seventeen miles west from New Haven, is a most remarkable example.[*] It gives a vivid emerald green light which continues for a long time.

---

* If the saline solutions are too strong they do not shine, but the light instantly appears on dilution with water. Ebullition destroys, but congelation only suspends the property, which appears again on thawing.—*Ure.*

Some varieties of marble, heated to a degree that would only make other bodies red, emit an intensely brilliant white light.—*Tur.*

The dried yolk of an egg becomes luminous if heated, and so does tallow, when thrown on a hot shovel or burning coals; both shovel and coals should be rather below redness. Some bodies ceasing to emit light by heat, become again luminous by increase of heat.

(*d.*) *Some emit light by percussion, friction or pressure.*—The Dolomite of Litchfield county in Connecticut faintly flashes, when pounded in a mortar; light is seen when lumps of sugar, or of quartz,[†] or borax, or bonnet cane, are smartly rubbed or struck together, in the dark,—certain varieties of tremolite and of blende give light when the point of a knife is drawn across them.[‡]

(*e.*) *Phosphorescence is seen in some animals.*

The glow worm, and several species of fire fly are examples. The luminousness of the waves of the sea in a storm, or under a vessel's bow, or of water taken from the sea and agitated, is very remarkable; this phosphorescence is owing to animal matter dissolved in the sea water, or to living animals, as the medusa, cancer fulgens,[§] &c.

When the sea water is filtered so as to remove the animals, it is said to lose its phosphorescent power.

Lt. H. Ingalls, of the U. S. Army, is of opinion that the phosphorescence of the ocean is owing to the ovula of fishes. He struck his arm, while bathing, against a soft mass, which emitted flashes two or three inches long, and he even convinced himself that there was a mild degree of heat, grateful to his touch. The jelly like masses, seen upon a beach after the retiring of the tide, he conceives to be the bodies in question; that these masses are phosphorescent, was proved by their emitting bright light, when irritated by the point of a pencil, especially in a particular opake point, appearing to be the punctum saliens of a living animal which the sun hatches, by degrees, from the jelly like mass, and the tide eventually shakes out. There is therefore the fullest reason to believe that the luminousness of the ocean is owing to animal matter.[‖]

Fresh water is not phosphorescent; the waves of the great North American lakes, although violently agitated by tempests, exhibit no luminous appearance. Air or its absence has no effect on phosphorescence.

(*f.*) *Phosphorescence is produced by chemical action.*

---

[*] Am. Jour. II, 142.

[†] Quartz phosphoresces even under water.—*Ure.*

[‡] Dr. Brewster's Edin. Phil. Jour. Vol. I. Nicholson's Jour. 8vo. Vols. XV, XVI and XIX.

[§] Tilloch's Phil. Mag. V. 37. and 38.

[‖] Trans. of Albany Institute.

Combustion is a familiar and very general example. Phosphorescence, without combustion, is seen in the case of sulphuric acid and calcined magnesia; when the magnesia has been recently and thoroughly calcined and the sulphuric acid is strong, there is almost always (especially if a few ounces of the materials be used) a flash in the dark, and sometimes it is visible in the day light.

Lime slaking in the dark, sometimes shows luminous points.—Light is emitted during the combination of sulphur and metallic filings, as copper and iron—of potassium and sulphur, iodine and phosphorus, &c.; that from iodine and phosphorus is very vivid. It is necessary only to throw a little iodine upon a small piece of phosphorus in a dry wine glass; the action is speedy or even instantaneous; a mild heat may bring it on when it is tardy, but we should be on our guard against explosion. The same remarks will apply to iodine and potassium, only the action is more violent, and the burning potassium is often thrown about the room.

15. LIGHT IS A CHEMICAL AGENT.

(*a.*) *It acts on vegetables.*—Etiolation or bleaching of vegetables by tying them up, takes effect in consequence of the exclusion of light. *Celery* is white, mild, and agreeable when growing beneath the earth, but acrid, and as is said, even poisonous if growing in the light; the *potatoe root* is affected in a similar manner by light. *Shoots of potatoes, turnips, cabbage, parsnip, carrot, &c.* are mild and white when sprouting in a moist, dark cellar, but if a beam of light crosses them, as from a crack, or a hole in a window, they become colored and pungent, and incline towards the light. The *inside leaves of heads of cabbage or lettuce* are white and tender; so are the inner coats of onions, the bottom parts of blades of grass, especially when shooting from beneath a flat stone, and *vines* when growing in the same manner.

The bark of trees is generally more colored than the wood—but *woods are occasionally deep colored,* as the dye woods and roots, logwood, fustic, brazil-wood, lignum vitæ, madder, turmeric, quercitron, alkanet, &c. and the heart of wood is sometimes more deeply colored than the superior layers, as in the red walnut.

Many causes operate besides light, e. g. heat, air, chemical composition, &c. But even *colored* woods generally grow deeper colored by exposure to light, e. g. mahogany, cherry, black walnut, maple, &c. as seen in common furniture. Red roses made to grow in the dark become white, or rather the trees that produce red roses in the light, produce white ones in the dark.*—Davy.

(*b.*) *Although the color of vegetables is not produced exclusively by light, it is owing principally to that cause.*

---

* Many shells possess rich and varied colors, which from their original situation could never have enjoyed direct access to light.

(*c.*) *Their pungency and aromatic properties depend very much upon the light.*

Plants growing in the dark "contain an excess of saccharine and aqueous particles;" they are destitute of color, odor, and pungency, but acquire these properties if transferred to the light.*

(*d.*) *Light is most abundant in the torrid zone,* and there the verdure is the most intense; there also we find the richest gums and resins and the most odorant aromatics, and the foliage is there most abundant; but other causes besides light contribute to these effects, as heat and moisture.

(*e.*) *Light extricates oxygen gas from fresh green vegetables,* which may be collected in an inverted bell glass, full of water, and containing the plant also. Carbonic acid gas is evolved in the night.

(*f.*) *Light is a stimulus to vegetables.*—Their leaves incline towards the light: plants growing in windows do this: some flowers open their petals to the light and shut them at night.

Camphor kept in glass bottles exposed to light, crystallizes in the most beautiful symmetrical manner, and more particularly on the side next to the light.

(*g.*) *Light sometimes weakens or discharges color.*—Yellow wax in thin layers becomes white; stamped goods, as curtains, and those stuffs that are colored in the thread, as carpets, have their colors faded by light: these colors are usually of vegetable origin, modified more or less by mineral mordants.

16. LIGHT ACTS ON ANIMALS.

(*a.*) *Light exalts the color of animals.—Worms, grubs, and larger animals that live in the ground,* are generally possessed of dull colors, without beauty or vivacity.

Birds and insects of night are generally of dull hues.—Owls, night-hawks, whip-poor-wills, certain varieties of snipes or woodcocks, &c. and the insects of summer evenings, have generally no beauty of color.

(*b.*) *The opposite is true of a great proportion of the various classes of animals that are much abroad in the day light.*

Generally the vivacity of color is greatest in the animals, birds and insects of the *tropical* regions, and the opposite is true of the *polar:* the *temperate,* as we might suppose, occupy a middle rank in these respects.

---

* Dr. Robinson, "in the drain of a coal work under ground, accidentally laid his hand upon a very luxuriant plant, with large indented foliage and perfectly white. He had not seen any thing like it, nor could any one inform him what it was.—He had the plant with a sod, brought into the open air in the light. In a little time the leaves withered and soon after new leaves began to spring up of a green color and of a different shape from that of the old ones. On rubbing one of the leaves between his fingers, he found that it had the smell of common tansy, and ultimately proved to be that plant, which had been so changed by growing in the dark."—*Rees' Cyclopedia.*

These can be regarded as only *general* truths subject of course to many exceptions and qualifications.

In *birds*, the parts exposed to the light, as the back and breast, are always colored, but the feathers beneath the wings and under the belly are usually white.—So the back and fins of fishes are colored, while the belly is white. Snakes and other reptiles, and the amphibious animals are distinguished in the same manner.

(*c.*) *The color of the human species is generally graduated in tolerable accordance with the quantity of light;* black people are not found perhaps any where except within the tropics, and white ones no where but in the northern temperate zone; but the state of society, food, habitations, employments, and many other causes, modify these results, and it is to be observed, that the colored people of polar climates, are all barbarians, living in smoke, filth, exposure and wretchedness.*

(*d.*) *The color of persons, of the various classes and conditions of society, accords with this view.*—Students and artisans, working within doors, and women, whose employments are, in this country, generally in the house, are of lighter complexions; while farmers, sailors, soldiers, &c. are more deeply colored. Many other causes, especially those affecting the state of health, do however modify these results.

(*e.*) *Light is necessary to health and cheerfulness.*—Animals and men, confined in darkness, become gloomy, and their health and their faculties are gradually impaired.

In the human subject, when long deprived of light, dropsy is said often to terminate life.

Other physical causes also operate, as want of exercise and bad air, and moral causes must also powerfully affect the human mind.

Even animals are affected, in a way somewhat analogous.

18. LIGHT ACTS ON MINERAL BODIES.

Nitric acid is decomposed into nitrous acid and oxygen gas.

Aqueous solution of chlorine gives out oxygen and muriatic acid, and most rapidly in the most refrangible rays.

Metallic oxides are, in some instances, decomposed; the *oxides of mercury* sometimes give running mercury.

White muriate of silver becomes dark, and even black, muriatic acid gas being formed.

Chlorine and hydrogen gases, in equal volumes, explode by the stroke of the solar ray and very quickly in the violet ray.

Phosphorus which is *white,* when first distilled in hydrogen gas, becomes colored, yellow and brown, by the action of light.

Substances wet with nitrate of silver, become dark, and even black, by exposure to the sun.

---

* See Dr. S. S. Smith's Essay; also the learned work of Dr. Pritchard, on the physical history of man.

19. Light produces magnetism.

This was first observed more than twenty years since by Morrichini, at Rome, and has been recently confirmed by Mrs. Somerville. (Ph. Tr.) A sewing needle, an inch long, being half covered with paper, had the other half exposed, during two hours, to the violet rays, which imparted north polarity; the indigo rays produced nearly the same effect, and the blue and green in a still smaller degree. The yellow, orange, red, and invisible rays were inert, having produced no effect in three days. Similar effects were produced when the needles were enclosed in green or blue glass, or ribands of the same color; one half being always covered with paper. The calorific rays produced no effect. In these experiments it was not necessary to darken the room.

*Iron** *ore* not magnetic, becomes so by exposure to light.†

REMARK.

When we have considered radiant heat, certain discriminations may be made between it and light, properly so called.

Some of the effects, above described, probably belong to one sort of solar rays, and some to another, but the facts are stated with reference to the undecomposed rays, as they come to us from the sun.

20. Sources of Light, *most of which are also sources of heat.*

1. *The Sun and fixed stars.*
2. *Combustion.*
3. *Heat without combustion*, as in an ignited stone.
4. *Percussion and friction.*
5. *Chemical action without combustion.*
6. *Electric and Voltaic action.*
7. *Animal power*, as in phosphorescent living animals.

"Organization, sensation, spontaneous motion and all the operations of life, exist only at the surface of the earth, and in places exposed to the influence of light. Without it nature would be lifeless and inanimate. By means of light, the benevolence of the Deity hath filled the surface of the earth with organization, sensation and intelligence."—*Lavoisier.*

PHOTOMETER.

Mr. Leslie, by having one ball of his differential thermometer‡ made of black glass, adapts it, as he conceives, to the measurement of light; but it seems difficult to distinguish in this case, between the effects of heat and of light, unless we adopt the opinion of the ingenious inventor, that light, when absorbed, is converted into heat.

---

* Fer oxidulé of Haüy. † Am. Jour. I. 89.

‡ For the notice of this instrument, see thermometers.

SEC. II. HEAT OR CALORIC.

GENERAL NATURE OF THIS POWER.

1. *The sensation produced in us, by a hot body, we attribute to a power which we call heat*—meaning that which is the cause of the sensation.

2. *This cause is unknown*—but, as that which excites in us the sensation of heat, produces at the same time, expansion in all the bodies, with which it communicates, both effects are attributed to one cause.

3. *The cause of heat and of expansion are therefore assumed to be one and the same*, and this unknown cause is called, in modern chemical language, *Caloric;* (Calor, Lat. Calorique, Fr.)* but to avoid pedantry and repetition, the terms, HEAT and CALORIC, are both occasionally used to denote the cause in question.

4. *Our sensations of heat and cold are dependent, principally, on the motion of Caloric.*

(*a.*) When it is entering our bodies, we feel warm or hot; when it is leaving us, we feel cool or cold, as the process is in either case more or less rapid.

(*b.*) More accurately speaking—*we feel hot, or cold, according as the quantity of heat, that enters or leaves us, is greater or less than the average quantity to which we are accustomed*—for heat is always flowing from us during life, and generally more rapidly than it is received, from without, as our natural temperature is higher than the average temperature of the air. If therefore, we lose more heat than we are, on the whole accustomed to lose, we feel cold, and the reverse.

(*c.*) *Cold is merely a negation of heat.*

The same person may feel heat and cold in different parts of his frame at the same time; for instance, by dipping at the same moment, one hand in cold, the other in hot water; or, by laying, simultaneously, one hand on ice, and the other on a living warm blooded animal.

---

* The new nomenclature of Chemistry had its origin in France.

The necessity of this reform arose from the progress of discovery. The language of Chemistry had become both erroneous and imperfect. Some newly discovered bodies had no names; many old names were false, and others barbarous or ridiculous. The period was about 1785, at which time the new nomenclature was perfected. The principal agents in this reform were Lavoisier, Fourcroy, Morveau, and Berthollet. Morveau proposed the measure in 1782. The nomenclature will be explained in detail, as the terms occur.—*See Jour. de Phy. Tome* 10. *p.* 370.

My much respected teacher, Professor HOPE, of the University of Edinburgh, at first colleague, and afterwards successor to Dr. Black, was perfectly familiar with the illustrious LAVOISIER, in the later periods of his life, and was fully acquainted with his discoveries and researches. Dr. Hope returned from Paris to Scotland, strongly imbued with the new views, and was the first public teacher in Britain who made them known, and who adopted the new nomenclature in his lectures. I had this from him when I was his pupil.

The late Dr. Pearson, of London, was also one of the first who promulgated the modern nomenclature and discoveries in Great Britain.

Three persons, in the same atmosphere, may find it cold, hot or temperate, according to their previous exposure—their state of health, or their clothing. To bring this to a trial, let one person come suddenly out of a bath of 98° or 100°; let another come from an ice house, and another from the temperature of 55°, into a room of the same degree of heat. The first will feel cold—the second warm, and the third will experience no change.

(*d.*) *Without motion there is no sensation.*

The motion of light - - -	produces	vision,
That of air, - - - - - -	"	hearing,
That of odorant matter - - - - -	"	smell,
*That of sapid substances, - - -	"	taste,
*And that of all bodies in contact with us,	"	feeling.

Lavoisier.

(*e.*) ***But mere sensation would not decide that there are not two causes,*** one of cold, and one of heat; or that cold is not the positive principle, and heat the negation.

Only reverse the reasoning—if we would contend that cold is the sole principle; or reason in both modes, if we would admit that both causes operate. For instance—Caloric enters us, or cold leaves us, and we feel warm; or cold enters us, or heat leaves us, and we feel cold.† But, to assign two or more causes, when one is sufficient is contrary to sound philosophy.

(*f.*) *The sun is a permanent source of heat.*

There is no permanent source of cold, and no fact can be stated on that subject which is not explained upon the supposition of the privation of heat.‡

5. *The common opinion, that some bodies are positively and inherently hot, and some cold, is erroneous.*

(*a.*) We could have no certain information on this subject, except from the changes in volume, or in their qualities, which various bodies undergo, when those that are supposed to contain more or less of heat are applied to them.

For instance, the thermometer is our criterion, and its fluid either shrinks or swells, according as the body in contact with, or near it, is colder or hotter than it.

Fluids become solid, and again fluid, or, in other words, freeze and melt, according to the variations in the quantity of heat.

---

* In the two latter cases, contact produces the sensation, but without motion it is soon diminished, and in the last instance, soon ceases.

† We must in this case, substitute *and* for *or*, if we would suppose both causes operating at the same time.

‡ The apparent radiation of cold will be mentioned hereafter.

(*b*.) *There is heat in every thing*, even in ice itself; and there is no reason to believe that we have ever attained the maximum of cold.

6. THERE ARE RAYS OF HEAT, DISTINCT FROM LIGHT.

(*a*.) *They obviously pass from all hot or warm bodies*, whether luminous or not.

(*b*.) *They flow from nearly all luminous bodies.*

(*c*.) *From living animals.*

(*d*.) *From hot water, and other hot fluids*, excluding those that require ignition to sustain their fluidity.

(*e*.) *From a hot ball of iron which is not luminous;* from a hot stone, a hot brick, or other heated incombustible body.*

(*f*.) *From a close stove*—supposing no chinks for the light to pass, and,

(*g*.) *Probably from all bodies whatever*, and at all temperatures, there is a certain amount of radiation of heat, although the colder the body is, the less the radiation will be.

7. RAYS OF CALORIC ARE EMITTED FROM THE SUN, and they are capable of being separated from those of light.

(*a*.) Dr. Herschel, using the telescope to look at the sun, employed colored glasses to diminish the light;—when their color was deep enough to screen the eyes, the glasses became hot and cracked; in some cases there was very little light, while the heat was painful to the eye, and some glasses transmitted much light but very little heat. He therefore examined the heating power of the different rays, separating them by a prism, and permitting the different colored rays in the well known order of red, orange, yellow, green, blue, indigo, violet, to fall on a delicate thermometer—two other thermometers being placed near, as standards; the thermometer which indicated the heat, lay upon an inclined table.

(*b*.) *The heat was greatest in the red, or least refrangible rays; and it was least in the violet, or most refrangible.* If when in the violet it was as 16—in the green, it was as 22.4, and in the red, 55.

(*c*.) *The greatest illuminating power was in the middle of the spectrum*, and it diminished either way.

(*d*). *When the thermometer was carried beyond the red ray, and in the same line, the fluid still continued to rise; the maximum effect was half an inch beyond the red, &c.;* one inch beyond, the same as in the middle of the red ray; the heating power was sensible at one and a half inch beyond the red ray.

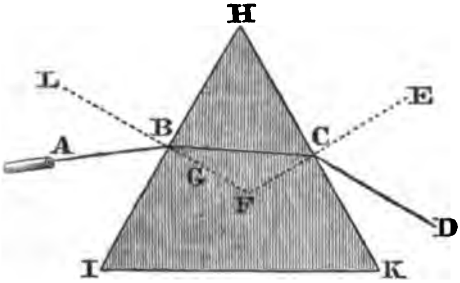
(*e*.) The focus of heat is probably not less than one fourth of an inch farther from the lens than the focus of light.†

---

* They are supposed to be hot, in order that the radiation may be evident: the radiation would exist, although in a less degree, if the bodies were cold.

† Phil. Trans. 1800, pp. 258—9.

The following figures represent the prism and prismatic spectrum.

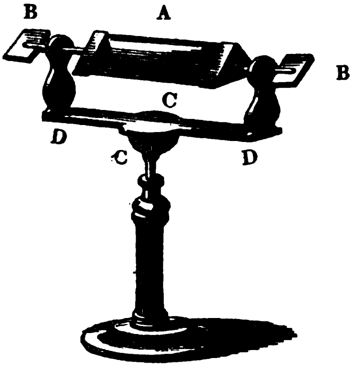


Should a ray fall upon a prism, as represented in the figure, in the direction of the line, AB; it will, on account of the obliquity of its approach, be refracted towards C, and emerging thence, obliquely to another surface of the prism, H C K, it will again be most attracted by that portion of the surface towards which it inclines. Consequently, it will be refracted so as to proceed in the direction of C D.

Thus it must be evident, that two surfaces of the prism have a concurrent influence, in bending the rays from their previous course, while in the pane, the influence of one surface is neutralized by that of the other.

The lines, L F, and E F, being perpendiculars to the surfaces of the prism, A B L, is the angle of incidence, and, G B C, the angle of refraction, to the surface at which the rays enter the prism. F C B, is the angle of incidence, and E C D, the angle of refraction to the surface, from which the rays emerge.—*Dr. Hare.*

A TRIANGULAR GLASS PRISM, CONVENIENTLY MOUNTED ON A UNIVERSAL JOINT.



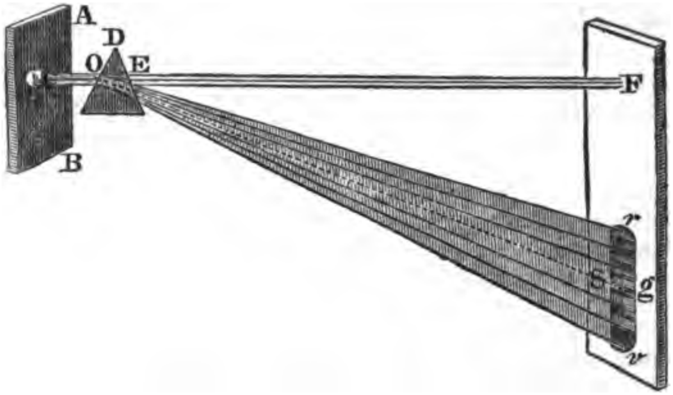
This figure represents a triangular glass prism, mounted upon a universal joint, supported by a brass stand, so as to be well qualified for the dispersion of light.

A, The glass prism, supported at each end by a pivot.

B B, Handles by means of which the pivots are turned, so as to make the prism revolve.

C C, Ball and socket, forming a joint, upon which the plate D D, may be moved, so as to assume any serviceable position.—*Dr. Hare.*

Let A B, represent a part of a window shutter of a room, into which light enters only through the hole C. If the light thus entering be received on a screen, a circular spot on it will be made luminous. But if a glass prism, D O E, be placed before the hole so that the light may fall upon the prism, perpendicularly to its axis, the rays which had before produced the luminous circle will be refracted and dispersed, so as to form the spectrum, *r g v*, consisting of the following colors arranged in the following order—red, orange, yellow green, blue, indigo, violet.



Dr. Hare.

(*f*.) *These experiments have been fully confirmed by those of Sir H. C. Englefield.—Mur.* In his experiments there could be no source of deception, because each kind of rays, first separated by the prism, was made to pass successively through a four inch lens covered by pasteboard, except at one place, where was a slit in the paper—the focus was thus formed in the air and the thermometers were there applied.

In Dr. Herschel's experiment, as the rays were thrown on a table, some fallacy might, possibly, have been suspected, from the reflection of the rays. In Englefield's experiment, the thermometer gave the following results.

Ray.		Time.		Quantity.		Ratio of the effect.
Blue	in	3′	from	55°	56°	1.
Green	"	3	"	54	58	4.
Yellow	"	3	"	56	62	6.
Full red	"	2½	"	56	72	7.2
Confines of red	"	2½	"	58	73½	6.6
In full dark, but near the red	in	2½	"	61	79	21.6

The difference in the heating power of the spectrum is so great, as to be perceptible to the naked hand.

(*g*.) *Berard confirmed Herschel's and Englefield's experiments substantially.**

---

* Ann. Phil. II, 163.

With him the heating power increased from the violet to the red ray. The greatest heating power was in the red extremity of the spectrum and not beyond it. His maximum of heat was where the thermometer was still covered by the red ray. The fluid in the thermometer sunk as it receded from the red ray, and entirely out of the red ray, where Herschel fixed the maximum, its elevation above the air around, was only one fifth of what it had been in the red ray.

(*h.*) *Red rays are considered as cheerful,* because warmth and therefore comfort, is found to be associated with them; such rays are emitted by burning charcoal and coke, and by a common wood fire; those from burning alcohol, especially if mixed with salt, are pale, and have very little heat in them, and are therefore regarded as gloomy.

Mr. Seebeck has proved that the place of the greatest heat depends very much upon the nature of the prism: thus, when it is of crown or plate glass, the maximum effect is in the middle of the red —if of flint, it is beyond the red; if a hollow glass prism be filled with water, the greatest effect is in the yellow; and if with sulphuric acid, it is in the orange; so that different substances appear to differ in their power of refracting caloric.* Still the important fact is confirmed, that there are rays of caloric, that they are differently refrangible from rays of light, and that they possess unequal refractive power.

8. RAYS OF CALORIC ALONG WITH RAYS OF LIGHT ARE EMITTED FROM ALL BURNING BODIES, AS WELL AS FROM THE SUN..

(*a.*) A plate of glass, presented to a common fire, intercepts the heat, but permits most of the light to pass, while it becomes itself hot.

(*b.*) A bright metallic plate reflects both the light and the heat, and does not become hot.

(*c.*) The same plate, if blackened with smoke, ink or paint, becomes hot, and then ceases to reflect either light or heat.

(*d.*) A glass mirror reflects only the light of a common fire, for it absorbs the heat and becomes sensibly hot; the focus is therefore luminous but not hot.

In the sun's rays it forms both a luminous and a hot focus, and therefore reflects both the heat and light.

(*e.*) A metallic mirror acts in the same manner, and also with a common fire, it reflects both the light and the heat; if blackened, it reflects neither, but becomes itself hot.

(*f.*) A lens, before an artificial fire, becomes hot, and forms only a luminous image; presented to the sun, it concentrates both the light and heat, and produces both a bright and a hot focus, while it scarcely becomes heated at all.

---

* Edin. Jour. of Science, No. 1, pa. 358.

(*g.*) The panes of a common window do not become heated by the passage of the sun's rays through them; or at most, the effect is scarcely perceptible.

(*h.*) Rays of caloric pass through glass with difficulty, if the temperature be below that of boiling water, but they traverse it with a facility always increasing with the temperature of the body emitting the heat, as it approaches the point where bodies become luminous.—*Hen.*

(*i.*) Calorific rays that have already passed through a glass screen pass through another with much greater facility. Rays emitted by a hot body differ in their power of passing through glass.

"A thick glass, though as permeable to light as a thin glass of a worse quality, or even more so, allows a much less quantity of radiant heat to pass; but the difference is so much the less as the temperature of the radiating source is more elevated."*

9. **RAYS OF CALORIC, EMITTED FROM HOT BUT NOT LUMINOUS BODIES, CAN BE REFLECTED BY MIRRORS, AND BROUGHT TO A FOCUS.**

Hot water, hot mercury, and hot, but not luminous solid bodies are good examples; e. g. a cannon ball, a stone, &c.

(*a.*) In making these experiments, either one mirror or two may be employed. The mirrors should be of copper, plated with silver; or, brass or tin will answer very well, if highly polished.

(*b.*) If one mirror be employed, the hot body should be placed in the axis of the mirror and the thermometer in the focus; if two mirrors are employed, the thermometer should occupy one focus and the hot body the other.

10. **RAYS ARE EMITTED BY THE SUN WHICH DO NOT PRODUCE EITHER HEAT OR VISION, BUT EFFECT CERTAIN CHEMICAL DECOMPOSITIONS OR COMBINATIONS.**

(*a.*) *Muriate of silver is tarnished or blackened by the sun's rays*—but in the prismatic spectrum, this effect is least in the red ray, and increases constantly towards the violet; the ratio of the blue and red rays is inversely, as 15 to 20—that is, to produce a given effect in fifteen minutes by the blue, requires twenty in the red.

(*b.*) Beyond the violet ray, the same effect is still produced in the dark.

(*c.*) Berard,† by a lens, concentrated that part of the spectrum, from the green to the violet, and by another the portion from the green to the red. The focus of the last was a white point, scarcely tolerable to the eye, but it did not alter the muriate of silver in two hours: the other focus was much less bright and less hot, but blackened the muriate in less than six minutes.

---

* De la Roche, Annals of Phil. II, 100.

† Ann. of Phil. II, 165.

(*d.*) Guiacum passed from yellow to green during the exposure at the violet end, and returned to yellow at the red end: this is supposed to be an anomaly, as Dr. Wollaston ascertained that the change to green is connected with the absorption of oxygen, and this principle is usually separated at the violet end.

(*e.*) It is said that phosphorus, which kindles easily at the red extremity of the spectrum, is extinguished at the violet end.

(*f.*) The combination of chlorine and hydrogen is effected rapidly by the red rays, but without explosion; but the aqueous solution of chlorine becomes muriatic acid most rapidly in the violet rays: "the violet rays produce upon moistened red oxide of mercury the same effects as hydrogen gas."—*Davy.*

(*g.*) Persons who had persisted in a long course of pills, formed by nitrate of silver (lunar caustic) and bread, acquired a blue tinge in the skin, and in one case this was deepened by exposure to light.*

CONCLUSIONS.

11. THE SUN BEAMS CONTAIN THREE DIFFERENT KINDS OF RADIANT MATTER.

(*a.*) *At least it is convenient, provisionally so to regard them,* as the effects are thus best understood.

(*b.*) *It is possible, however, that they may all be varieties of one thing,* and the apparent difference may be owing to unknown causes.

(*c.*) The rays of the sun then appear to contain

A. *Rays that illuminate, but do not cause warmth or expansion;* they may be called *colorific rays.*

B. *Rays that cause warmth and expansion, but do not illuminate;* they are opake, and may be called *calorific rays.*

C. *Rays that produce neither color, nor heat, nor expansion, but that cause certain chemical effects;* they also are opake and may be called *chemical rays:* by some they have been called *de-oxidizing or hydrogenating rays.* The first term is preferable, on account of its brevity.

12. *These three kinds of rays all come from the sun in company;* hence the triple effect of the solar beam, in warming and causing expansion, in illuminating or imparting color, and in producing certain chemical effects.

13. *In the moon's rays, there is chiefly light with little or no heat.*

Mr. Brande has ascertained, that the lunar rays do not blacken muriate of silver.†

Popular opinion ascribes to them the power of stimulating vegetation, and of causing putrefaction in fish and other animal bodies, upon which they may chance to fall.

14. *Culinary fire, as all know, emits both the luminous and the heat-*

---

* Cooper's Thomson, note, edit. 1818, Vol. I. p. 34.

† Ure's Dict. p. 567.

ing rays;—but it has not been ascertained that the de-oxidizing chemical rays are present.*

15. *The physical laws of all the three varieties of rays are nearly the same, differing a little in the amount of the effect.*

(*a.*) *They are refrangible;* this is proved by their passing through the prism, and being all made to deviate from their course.

(*b.*) *They are refrangible in different degrees;* and this is true, whether we compare one sort of rays with another, or the rays of one kind individually among themselves.

(*c.*) *Some rays of each kind are equally refrangible,* and are therefore found in company through the whole spectrum.

(*d.*) *Some rays of caloric are less refrangible than any of the other rays of either kind;* therefore they are found outside of the red rays in the dark.

(*e.*) *Some of the chemical rays are more refrangible than any other, of either kind;* hence they are found outside of the violet ray, and in the dark.

(*f.*) *The spectrum, then, is composed of the three sorts of rays,* but it is terminated by calorific rays on one side, and by chemical rays on the other; on both wings it has opake rays, but of different kinds.

(*g.*) *All the kinds of rays are reflexible.*—This is evident from the effect of mirrors; and Scheele long ago, ascertained the equality of the angles of incidence and reflection.

(*h.*) At a given distance from the radiant point, the intensity of both heat and light† is inversely as the square of the distance, *e. g.* At the distances 2, 3, 4, it is as 4, 9, and 16 inversely.

16. *It is probable that all the three kinds of rays are emitted from the sun, and other sources with equal velocity.*

We are not informed as to what is the cause of the differences between solar and culinary heat.

17. It is evident, that *the particles of all the three varieties of rays are minute,* to a degree beyond our powers of conception; probably they are equally minute, but of this we are not certain.

18. It is evident, therefore that *we cannot expect to ascertain the weight of either of these kinds of rays;* as already remarked, our organs, and our instruments are too coarse for such delicate trials.

19. *There is a great analogy between light and heat*—they agree in nearly all their physical properties; but light produces vision and colors—caloric, expansion and heat.

(*a.*) *Light cannot be, at all, imprisoned.*—When the source from which it flows is intercepted, except *in the case of the solar phos-*

---

* Neither muriate of silver, nor a mixture of chlorine and hydrogen gases, was affected by the concentrated light from the burning carburetted hydrogen gases; but the light from electrized charcoal speedily blackened the muriate, and exploded the chlorine and hydrogen, or caused them to combine quietly.—*Brande.*

† The chemical effect probably follows the same law; possibly also the magnetic.

phori, it vanishes *instantly*, and leaves no trace behind—all is darkness.

(*b*.) *Light can be entirely excluded.*—Although it seems to penetrate and enter all bodies, it shines through none but those that are called transparent or translucent.

(*c*.) *Heat can be partially imprisoned.*—When the sources from which it flows are intercepted, its effects do not instantly vanish, but decline gradually.

(*d*.) *Heat cannot be entirely excluded.*—It makes its way, more or less rapidly, through all kinds of matter.

EFFECTS OF HEAT, OR CALORIC, AND PRINCIPAL DIVISIONS OF THE SUBJECT.

Certain effects on the form, and other properties and powers of bodies, are observed to arise from the addition and abstraction of heat. They may be embraced under

I. *Expansion,*
II. *Distribution of temperature,*
III. *Congelation and liquefaction,*
IV. *Vaporization and gazification,*
V. *Natural evaporation,*
VI. *Ignition,*
VII. *Capacity for heat—Specific Heat,*
VIII. *Combustion.*

APPENDIX.

The sources of heat and cold.

I. EXPANSION.

1. *By expansion, is intended an increase of the three corporeal dimensions, length, breadth and thickness.*—Contraction is of course the opposite of this.

(*a*.) The entrance of heat into a body produces the same result, in regard to its dimensions, as if more matter were added to it.

(*b*.) The abstraction of heat gives, in this respect, the same result, as if matter were taken from the body all around.

Swelling and shrinking, then, are produced by heating and cooling.

(*c*.) *The absolute weight of a body is not altered,* if the weight be estimated in vacuo; but if it be weighed in any surrounding medium, whose density does not vary during the experiment, the *specific gravity* of the body will be found to change with the temperature.

(*d*.) The experiments are supposed to be conducted at such a temperature as not to produce decomposition.

2. *Bodies in all the three states, solid, fluid and aëriform, are subject to the law of expansion.*

(*a*.) *As an instance of the expansion of solids, an iron cylinder neatly turned, and fitted to a gauge by which its dimensions are measured, answers very well.*—Its length is received between two projections, and its diameter in a hole. If it fit these dimensions at the common temperature—it will be too large if made red hot, and too small if cooled by ice.

Cylinder.

Length.

Diameter.

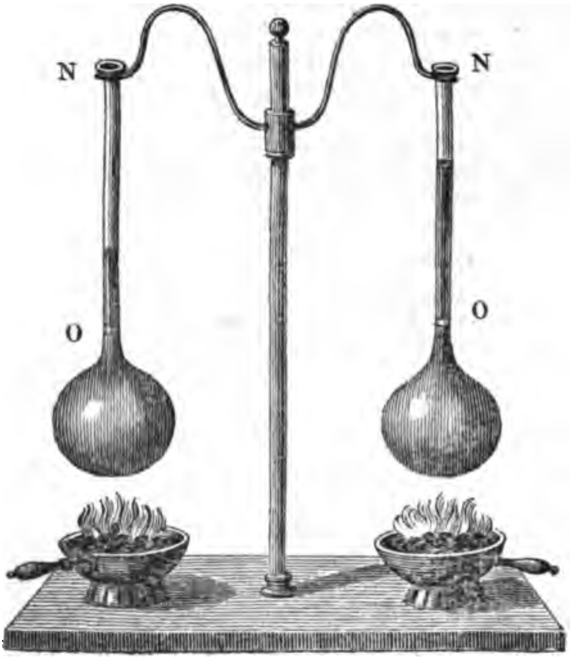
An Iron ball just fitting an iron ring so as to pass through it when cold, will not pass when red hot, but when cold will pass as before. —L. U. K.

(*b.*) A pear shaped glass, thin at bottom, with a perforated cork, containing a long narrow tube, inserted into the neck—the glass being filled with a colored fluid, exhibits strikingly the expansion and contraction of fluids; it is necessary only to heat and cool the ball.

Alcohol is more expansible than water, but on account of its combustibility, care should be taken that none of it is spilled into the fire; a scale may be attached to the tube, and then the expansions and contractions will be very visible. The thermometer demonstrates the same facts.

EXPANSION OF LIQUIDS.—*Dr. Hare.*

Liquids are expanded when their temperature is raised; and some liquids are more expansible than others.



3. *In general, different solid or fluid bodies expand variously, by the same amount of heat, and no satisfactory theorem has been discovered on this subject:* the facts are ascertained by experiment. The following metals are arranged in the order of their expansibility, the *most expansible* being placed first; zinc, lead, tin, copper, bismuth, iron, steel, antimony, palladium, platinum.—*Henry.*

It is said by Dr. Ure, that equal increments of heat produce equal degrees of expansion in metallic bodies:* and that the reverse is true for the decrements.

Table of expansion, by Ellicott.†

Gold.	Silver.	Brass.	Copper.	Iron.	Steel.	Lead.
73°	103°	95°	89°	60°	56°	147°

By a table of Smeaton, (Mur.) zinc appears to exceed lead in expansibility. There appears to be no relation between the density and expansibility of solid bodies, gold being less expansible than brass or lead: but there is a tolerably regular relation between the expansibility and the fusibility; e. g. antimony, bismuth, tin, lead and zinc being most expansible and most fusible; in Smeaton's table, antimony is stated as expanding less than iron, and bismuth than copper, but these deviations may arise from errors in the experiments.‡

4. *Gases are the most expanded, and with them all aëriform bodies: fluids are much less expanded than gases, and solids vastly less than fluids.*

Beneath is Mr. Dalton's table of some common liquids: the volume at 32° is denoted by 1; the expansion is for 180°, from 32° to 212°.

Mercury, - - - - - -	.0200 $= \frac{1}{50}$
Water, - - - - - - -	.0446 $= \frac{1}{21}$.5
——— saturated with salt, - - - -	.0500 $= \frac{1}{20}$
Sulphuric acid, - - - - - -	.0600 $= \frac{1}{17}$
Muriatic acid, - - - - - -	.0600 $= \frac{1}{17}$
Oil of turpentine, - - - - - -	.0700 $= \frac{1}{14}$
Ether, - - - - - - -	.0700 $= \frac{1}{14}$
Fixed oils, - - - - - - -	.0800 $= \frac{1}{12}$.5
Alcohol, - - - - - - -	.0110 $= \frac{1}{9}$
Nitric acid, - - - - - - -	.0110 $= \frac{1}{9}$

Generally the expansion of fluids increases as we ascend the scale. Mr. Dalton,§ thinks that the expansion of fluids is as the square of the temperature from the point of congelation or of greatest density. This is not sufficiently confirmed by experiment.‖

5. *Caloric introduced among the particles of bodies is a power of repulsion tending to produce expansion.*

---

* Phil. Trans. 1818. † Phil. Trans. xlvii. 485.

‡ Murray, Vol. I. p. 168, 2d edition. § New system of Chemical Philosophy.

‖ Murray, I. 173, 2d edition.

(*a.*) The antagonist power is cohesion.

(*b.*) Therefore, as regards all the three forms of matter, solid, fluid, and gaseous, the expansion varies with the ratio of these two forces; only one of which exists in the gases.

6. GASES AND ALL AERIFORM BODIES EXPAND ALIKE.*

(*a.*) *One body, of this class, corresponds with one of another class;* e. g. carbonic acid gas with hydrogen, steam with vapor of alcohol, &c.

(*b.*) *The same body corresponds with itself,* equal variations of temperature producing equal variations of volume, in different parts of the scale.

(*c.*) *The reason of this exception is obvious, as in aëriform bodies there is no cohesion to overcome;* the power of the heat is, therefore, the same upon them all.

7. *Fluids expand very unequally.*

(*a.*) In general, the lower the boiling point of a fluid is, the more it is expanded by heat, and vice versa, as is seen in ether, alcohol, water, and mercury.

(*b.*) In general, also, the expansibilities of liquids are inversely as their boiling temperatures.—*Thomson.*

(*c.*) In any given liquid, the expansibility increases with the rise of temperature, and those are the most equal, whose boiling point is the highest.

(*d.*) The expansibility of fluids does not follow the ratio of the density.

(*e.*) It increases very rapidly as we approach the boiling point.

---

[*] Mr. Dalton of Manchester, (Eng.) and Gay Lussac of Paris, ascertained, by numerous experiments, that the expansion of all bodies, in the form of air, is the same, for equal additions of heat; and moreover, that the expansion of any one aëriform body is nearly, although not perfectly, equable for equal additions of heat, in different parts of the scale.

It was formerly believed, that every different gas was affected differently by heat, and tables of expansion of the different gases were constructed, but this variation was owing to the presence of water in all experiments before those of Dalton and Gay Lussac, as the vapor mixing with the gas under examination, must necessarily falsify the result.

100	cubic inches of	common air,	in passing	from	212°	to	1035°	become	250.	cub. in.
100	do.	common air,	"	"	32°	"	212°	"	137.5	"
100	do.	water,	"	"	do.	"	do.	"	104.5	"
100	do.	iron,	"	"	do.	"	do.	"	100.1	"

The expansion of air is then eight times greater than that of water, and that of water forty five times greater than that of iron. The expansion of any one gas apparently diminishes a little as the temperature increases; it is however probable that this difference, as it is so very small, is only apparent.

Dalton informs us that the expansion of 100 cubic inches of air, from 55° to 133½°, or for the first 77½°, was 167; and from 133½° to 212°, or the second 77½°, it was only 158: but if this difference be imputed to inaccuracy, we may conclude that the expansion is equable. Aëriform bodies expand one four hundred and eighty third part of their volume for every degree of Fahrenheit between freezing and boiling.—Vide Manches. Memoirs, V. 598; Th. I. 338; and Ann. de Chim. xliii. 137, and v. 43.

8. *Solids expand very unequally, and as far as has been discovered,* follow no general law.*

9. *There are partial exceptions to the law of expansion in certain parts of the scale of heat*, but none on the whole, for through a wide range of temperature, all bodies expand by heat and contract by cold.

(*a.*) *Solid iron, bismuth, and antimony*, float on the surface of their respective fluids, formed by melting.

Such metals and their compounds are peculiarly fitted for taking impressions from moulds, as by their expansion in cooling, they fill every part, and copy the most delicate ramifications.

(*b.*) *The expansion in freezing is generally attributed to a kind of crystallization*—but mercury, and nitric and sulphuric acids contract, although they suffer a partial crystallization.

(*c.*) Salts generally expand in crystallizing, and frequently break the bottles containing them.

(*d.*) *Water is the most remarkable exception*, but it exists only within a limited number of degrees.

In cooling, it attains its maximum of density at 40°, when it begins to expand, and continues to do so as it cools below 40°; its expansion is the same for any equal number of degrees above and below 40°; e. g. at 32° and 48°.

If water be cooled below 32° without freezing, it goes on expanding, and the same relations of density are maintained.

Pure ice floats on water, about one eighth or one ninth of its volume being out, as is seen to a certain degree, in the icebergs.†

(*e.*) The fact respecting water's being an exception from the law of expansion, is well exhibited, by taking two thermometer balls with tubes attached, and filling one ball with water and the other with alcohol; both may be immersed in melting snow, or in freezing water, and the difference will be very manifest, if the experiment be commenced above 40°. The alcohol will sink regularly, but the water at 40° will begin to rise in the tube, and will continue to rise till it freezes.

(*f.*) *Water, in the act of freezing, expands more than it does when heated from the freezing to the boiling point.*‡

---

* It has however been ascertained by Petit and Dulong that at high temperatures, solids dilate in an increasing ratio.—*Ann. de Ch. and Phy. Vol. 7, and Turner's Chem. p.* 20. For a table of the expansion of various substances, see the latter author same page.

† Anchor-ice. Is it formed on the bottom of running streams, on account of the conducting power of stones?

‡ This is beautifully illustrated, by immersing in a freezing mixture, a ball filled with water, and having a tube attached to it; as the fluid approaches freezing, and especially when it begins to freeze, it will rise out of the top of the tube.

The sp. gr. of water at 60° being assumed at 1, that of ice at 32°, is only .92.*

(*g.*) Were it not for the exception above described, water would begin to freeze at the bottom of rivers and lakes.

10. *Cause of the expansion of water in freezing, and for eight degrees above.*†

(*a.*) There can be little doubt that it is owing to crystallization, depending on corpuscular attraction, which begins to operate even before congelation. Water in freezing, assumes a linear arrangement: lines of ice intersect each other at 60° and 120°; this is seen distinctly in a shallow freezing pond, or in a basin of water: also in snow flakes, which are usually stars of six rays, or confused bundles of prismatic crystals; distinct crystals, prisms of six sides, are often seen on a cellar wall in winter, or in a moist bank, and hoar frost is a collection of crystals of ice.

(*b.*) The particles of water are supposed to be endowed with a kind of polarity, which causes the volume to expand, in consequence of the attraction of certain points, edges or angles.

(*c.*) An illustration is derived from magnetic needles thrust through corks, and thrown upon water; they would arrange themselves as the aqueous particles are supposed to do in crystallizing.—*Dr. Black.*

"When the freezing of water is examined by the microscope, this peculiarity of arrangement can be observed, the lines shooting out from each other at an angle either of 60° or of 120°."‡

11. *Effects of unequal expansion of water, and of its expansion in freezing.*

(*a.*) The bursting of domestic vessels in which water freezes; the flaking of the glazing from earthen vessels.

(*b.*) The bursting of water pipes, of wood or metal, when not adequately protected.

---

[*] Webster, p. 25.

[†] This expansion was denied by Mr. Dalton, who attributed it to the contraction of the glass exceeding that of the water, and vice versa—its expansion exceeding that of the water, in the specified degrees between 32° and 40°.

This question was however fully settled by Dr. Hope, and Mr. Murray, and this inequality is considered as well established. See the controversy ably stated in Murray, Vol. I. p. 194, &c.

Sir Charles Blagden ascertained that when water is prevented from freezing at 32°, by being kept perfectly still, the water still continues to expand, even for ten or more degrees below the ordinary freezing point, and this in even a greater ratio; and if the freezing point be reduced, by mixing salt with the water, the contraction begins at about the same distance from the point at which the particular solution does freeze.

"Mr. Dalton succeeded (Manchester Memoirs, v. 374,) in cooling water down so far without freezing, that from expansion, it had risen as high as the point to which it would have been raised had it been heated to 75°. "Its real temperature must then have been 10°. On freezing, it darted suddenly up to 128°."

[‡] Murray, 2d Ed. Vol. I. p. 182.

(*c.*) The raising of pavements, and of the surface of the ground, like a honey comb, thus breaking and preparing it, so that the vegetable fibres can penetrate it.

(*d.*) The throwing down, or distortion of stone walls, in moist land.

(*e.*) The cracking of timber, and even of rocks, sometimes with explosion, in very cold countries.

(*f.*) The bursting of closed cannon and bomb shells, when water is congealed in them.

Huygens burst an old cannon, and Major Williams burst bomb-shells at Quebec. In one of his experiments, "an iron plug, 2 ½ pounds weight, was projected from a bomb-shell, to the distance of four hundred and seventy five feet, with a velocity of more than twenty feet in a second."

(*g.*) Water, being confined by means of a moveable plug or stopper, in a strong brass tube, three inches in diameter, raised seventy-four pounds, when it froze.—*Boyle.*

(*h.*) The Florentine academicians burst a hollow brass ball, one inch in diameter, by freezing the water with which it was filled. Muschenbrœck, calculating from the tenacity of brass, and the thickness of the ball, inferred, that the expansive force was equal to twenty seven thousand seven hundred and twenty pounds.

12. *But for the inequality of water in contracting, just before its congelation, the globe would not be long habitable.*

(*a.*) There are both ascending and descending currents in water, while cooling or heating.

(*b.*) In the case of cooling water, these currents, while unobstructed, tend to cool it equally.

(*c.*) In consequence of the exception that has been stated, they are arrested at 40°, and then the surface water does not descend any more.

(*d.*) It remains, is cooled, and freezes, and the ice, being a bad conductor of heat, greatly retards the freezing of the water below.

(*e.*) Thus only a few inches, or at most feet of ice are formed, and the next summer is sufficient to thaw it.

(*f.*) Were it not for this peculiarity, the deep rivers and lakes in cold latitudes would freeze to the bottom, and therefore would never thaw again, as the summer would not be long enough for that purpose.

(*g.*) The process would, every winter, advance farther and farther towards the equator, and ultimately the ocean would freeze as solid as stone.

(*h.*) *Thus, animal and vegetable life would be finally extinguished.*

(*i.*) All this mischief is prevented by this, apparently, trifling and really solitary exception, evidently instituted on purpose by the Creator, one of whose characteristics it is, to effect the greatest results by the smallest means.

(*j.*) "The sheet of ice which often covers the small seas, as well as the rivers and lakes, not only preserves a vast body of heat in the subjacent water, but when it thaws, the fish are not destroyed by the cold; for not a particle of the cold surface water can descend until a change in the atmosphere has taken place, so as to raise the temperature of the whole of the water, at least ten degrees.*

13. *Popular uses of expansion and contraction.*

(*a.*) *Iron hoops and tires are heated red hot*, and suddenly cooled to bind the parts of carriage wheels, of burr millstones, &c.

(*b.*) *Clocks and watches gain in cold weather*, owing to the contraction of the metal, and vice versa.

A pendulum vibrating seconds, by a change of temperature of 30° will alter its length about $\frac{1}{5000}$ part, which will change its rate of going eight seconds a day. Or if the ball of a pendulum vibrating seconds be lowered $\frac{1}{100}$ of an inch, the clock will loose ten seconds in twenty four hours.—*Hen.*

(*c.*) *The Compensation pendulum* is easily explained, by a model or diagram; one kind, called the gridiron pendulum, consists of bars of different expansibility, and having different points of support, the opposite expansions balancing each other. Harrison employed three bars of steel, and two of a compound of zinc and silver, and they were so arranged that the expansion of the steel counteracted that of the other metals, so that the pendulum did not alter in length. Graham substituted for the bob of the pendulum, a glass cylinder about six inches deep, and holding ten or twelve pounds of mercury. the expansion of which upward, compensated for that of the steel pendulum rod downward.—L. U. K.

(*d.*) *The cracking of thick glass, by sudden heating or cooling, is owing to unequal expansion;* thin glass does not crack, because the heat makes its way through the glass so rapidly, that the internal and external expansion are nearly alike; otherwise there would be a strain, and glass always cracks on the colder surface, whether hot glass is suddenly exposed to cold, or the reverse.

(*e.*) *Expansion and contraction, by temperature, is capable of overcoming great force.*

The two side walls of a gallery at the *Conservatoire des Arts et Métiers*, being pressed outward by the incumbent weight, M. Molard perforated the walls on opposite sides, and introduced strong iron bars, whose ends were left to project beyond the walls, and were furnished with strong circular iron plates, fitted on so as to screw.

The bars, being then heated, increased in length, and the plates now separated from the wall, were screwed up so as to touch it. The bars, on cooling, contracted, and drew the walls closer together.

---

* Parkes' Chemical Essays, Vol. I. p. 61.

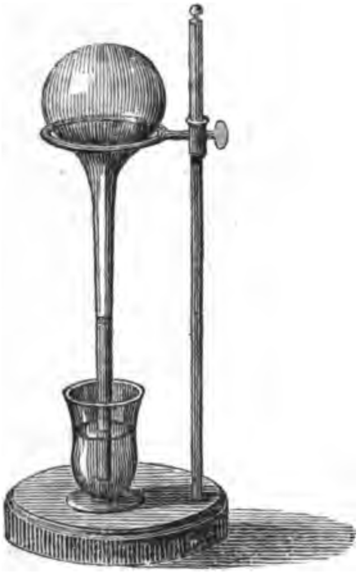
The process being repeated, the walls were brought into the perpendicular position, and if necessary, could have been curved inward. —L. U. K.

THERMOMETERS, CONSTRUCTION, USE, &c.

1. *The common thermometer, and most pyrometers, operate upon the principle of expansion.*

(*a.*) *The thermometer was probably invented by Sanctorio*, an Italian physician of the seventeenth century. His thermometer was merely a ball blown on the end of a glass tube, and inverted in a fluid; it was consequently subject to the pressure of the atmosphere, a change in which might cause a movement of the fluid, although the temperature should be stationary. This thermometer is entirely unfit for being used in fluids—still it is very useful, as an air thermometer, for measuring minute variations of temperature.

Air Thermometer of Sanctorio, on a large scale.



The bulb of a mattrass is supported, by a ring and an upright wire, with its neck downwards, so as to have its orifice beneath the surface of the water in a small glass jar. A heated iron being held over the mattrass, the contained air is so much increased in bulk, that the vessel being inadequate to hold it, a partial escape from the orifice through the water ensues. On the removal of the hot iron, as the residual air regains its previous temperature, the portion expelled by the expansion is replaced by the water.

If in this case the quantity of air expelled be so regulated, that when the remaining portion returns to its previous temperature, the liquid rises about half way up the stem, or neck, the apparatus will constitute an air-thermometer. For whenever the temperature of the external air changes, the air in the bulb of the mattrass must, by acquiring the same temperature, sustain a corresponding increase or diminution of bulk, and consequently, in a proportionable degree, influence the height of the liquid in the neck. This thermometer is very sensible and would be very accurate, but that it is influenced by the variations of atmospheric pressure as well as by thermometrical changes.—*Dr. Hare.*

(*b.*) *Leslie's differential thermometer.*—For the construction of this instrument, a ball is blown at each end of a glass tube bent twice at right angles.

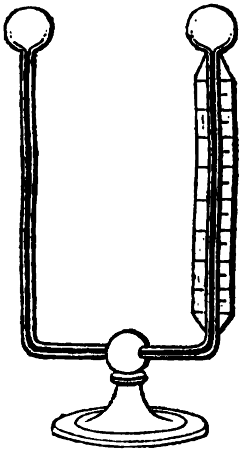
The tube contains usually sulphuric acid colored by carmine—the balls contain air, which, as well as the contained fluid has no communication with the atmosphere.

(*c.*) *It indicates only the difference of temperature between the two balls.*—It is very useful in delicate experiments on heat, where the variations of temperature are minute.

(*d.*) *Howards improvement of Leslie's thermometer.*

Dr. Howard of Baltimore,* has substituted ether for the sulphuric acid—the ether is boiling when the instrument is sealed, and therefore there is a vacuum over the fluid, except that the space is filled with the vapor of ether; this instrument is vastly more sensible than Leslie's original one, and with it the heat was believed to be discovered in the moon's rays by Dr. Howard.†

DIFFERENTIAL THERMOMETER.



This instrument consists of a glass tube nearly in the form of the letter U, with a bulb at each termination. In the bore of the tube there is some colored liquid, as for instance, sulphuric acid, alcohol, or ether.—When such an instrument is exposed to any general alteration of temperature in the surrounding medium, as in the case of a change of weather, both bulbs being equally affected, there is no movement produced in the fluid; but the opposite is true, when the slightest imaginable calorific influence exclusively affects one of the bulbs. Any small bodies, situated at different places in the same apartment warmed by a fire, will show a diversity of temperature, when severally applied to the different bulbs.—*Dr. Hare.*

2. Construction of the common thermometer.

(*a.*) *Take a glass tube, of uniform bore, sealed at the glass-house.*—Its uniformity is ascertained by introducing a little mercury, and letting it pass along the tube, from end to end, measuring it, at short intervals, with a scale or dividers.*

---

*Lond. Quar. Sci. Jour. Vol. 8, pa. 219. † Am. Jour. Vol. II, pa. 329.

(*b.*) *Although the tube should not be quite uniform, it may be still used.*†

(*c.*) *To blow the ball, the instruments wanted are the blow pipe, and an elastic gum bottle* which is useful, perhaps necessary, where the thermometer must be exact—that is free from air and moisture. We need also pliers and some bladed instrument. The glass is melted, drawn in two, and thus hermetically sealed at one end, while it is opened at the other by cracking it, after marking it with a file; the end on which the ball is to be, is then rounded, by alternately holding it in the flame and pressing the hot glass against the blade, to accumulate as much as is needed. The bulb is next blown by the mouth or the elastic bottle, and this part of the operation requires a kind of skill which can be acquired by practice alone.

(*d.*) *To fill the ball with mercury.*

First heat the mercury in a ladle, to drive off moisture and air; filter it by making it pass through pin holes in a paper depressed into a wine glass, in the form of a funnel; next hold the ball over a spirit or an Argand's lamp, the open end of the tube being immersed in the mercury, turning the ball to prevent fusion or collapse, and holding it in the heat as long as the air continues to issue freely; then withdraw it and the atmosphere will raise a column of mercury that will fill the ball, one third or one half. Now bring the ball again over the lamp, with the mercury exposed to the heat until it boils, when the metallic vapor will expel most of the remaining air; on withdrawing it from the heat, the mercurial vapor will be condensed, and the tube having its open end still immersed in the mercury, the latter will rush in, and nearly or quite fill the ball.

(*e.*) *To boil the mercury, for the purpose of expelling the remainder of the air.*

Tie a small paper funnel to the open end of the glass tube, having joined its edges by paste or sealing wax—throw in a small globule of mercury to act as a valve—then boil the mercury, holding the tube vertically over the flame of the spirit lamp, and surrounding the tube with thick folds of paper, protecting the fingers still farther by a glove.

(*f.*) *When the mercury boils quietly, and the ball is readily filled on being withdrawn from the heat, we presume that the air is all expelled.*

---

* If the bore be very small, the mercury must be introduced by the elastic gum bottle, by tying it fast—compressing it strongly with the hand to expel the air, and then allowing it to resume its former shape, when a portion of mercury will rise into the tube.

† See American Journal, Vol. IV, pa. 398, for the method of Mr. Kendal, a self-taught artist.

After the ball has been cooling for a few minutes, the excess of mercury is poured out, and the column allowed to subside.

(*g.*) *To try whether the range of the mercury will be correct.*

Immerse the ball in melting ice or snow—the mercury should not sink within the ball—immerse it in boiling water, or, which is better, in steam. In this case, the mercury should not rise so high as the top of the tube and these two points, the freezing and the boiling should fall higher or lower according to the use that is to be made of the thermometer, for measuring high or low degrees—that is, extremes of heat or of cold; if intended for both, there should be sufficient room both above and below these two points.

(*h.*) *If there be not mercury enough, warm the ball in a candle,* and let the column, as it reaches the summit, be united to more quicksilver in a wine glass, quickly reversing and plunging the tube for that purpose.

(*i.*) *If there be too much mercury, let a little of it be expelled,* by warming the ball, and then in either case, the mercury must be adjusted as regards the freezing and boiling points, by a new immersion in melting snow or ice and in steam.

(*j.*) *To close the tube to exclude the atmosphere.*

Draw the end of the tube in two by the blow pipe, and it will be of course hermetically sealed; then break the fine point so that it may be merely open; next warm the ball, so that the mercury will rise and fill the entire tube, and just as it is about to issue from the orifice, things being previously adjusted for that purpose, direct the blowpipe flame upon the point, and seal it; if correctly done, the mercury will then roll, backward and forward, without breaking the column and without impediment.

(*k.*) *Final adjustment of the fixed points of freezing and boiling.*

A new exposure to the melting ice and to the steam of boiling water, will now give us, by inspection of the top of the mercurial column, the important points of freezing and boiling water, which must be marked on the glass by a diamond or a file.

(*l.*) *Graduation of the instrument.*—The space, between freezing and boiling water, is now to be divided into one hundred and eighty equal parts; freezing water will be 32 and boiling water 212°.

This division is arbitrary. It was adopted by Fahrenheit of Amsterdam, after whom the thermometer, thus graduated, was called. The 0 of this scale indicated the greatest cold observed in Iceland, and it was supposed to be as great as would probably ever occur in philosophical experiments. The scale is extended above boiling water to any desired degree, and below 0, by numbers reckoned the opposite way, which are considered as minus degrees and marked with the correspondent arithmetical sign, while the degrees above 0 are written without any sign.

(*m.*) *Other points usually marked on the scale.*—Blood heat is marked 98° for the human subject; fever heat 112°; the mean summer heat of the day light in temperate climates,[*] 76°; ether boils at 98°; alcohol 176°; mercury 656°.[†]

(*n.*) *Other scales used in different countries.*

As the division of a thermometrical scale is entirely arbitrary, it varies in different countries. In the thermometer of Réaumur freezing water is 0 and boiling water 80°.

In Spain and Italy, this thermometer is still used; but in France, since the revolution, Réaumur's has been discarded, and that of Celsius adopted, under the name of thermomêtre centigrade, in which freezing water is 0, and boiling water 100°. To reduce the degrees of Fahrenheit to those of the centigrade, substract 32, then multiply by 5 and divide the product by 9, because each degree of Celsius $=\frac{5}{9}$ of 1° of Fahr.

In converting the centigrade degrees into those of Fahrenheit, double the centigrade number, subtract $\frac{1}{10}$, then add the constant number 32. Thus, $10°$ cent. $\times 2=20-\frac{1}{10}=20-2=18+32=50°$.

To convert the degree of Fahrenheit into those of Réaumur, subtract 32°, multiply the remainder by 4 and divide the product by 9: or, the reverse, that is, multiply the Réaumur degree by 9, divide by 4 and add 32.[‡]

Mr. Murray proposed another division of the thermometrical scale; namely, into one thousand degrees, counting from −39°, the freezing point of mercury, to 672°, its supposed boiling point. The advantages proposed, are a more minute division, the avoiding of negative degreesand fractional parts, &c.[†]

Thermometrical scales are often compared, by drawing a diagram to exhibit them side by side, when any line drawn at right angles to the scale will cut the correspondent degrees, which may thus be read by inspection.

In Russia, De Lisle's thermometer has been adopted; in that, freezing water is 150°, and boiling water or melting snow is 0; a very awkward division.

(*o.*) *Principle of the graduation.*

This is founded upon the fact that the temperature of freezing water and of melting snow or ice is the same, all the world over; and that pure water (the pressure of the atmosphere being the same) boils every where at the same temperature.

---

[*] Probably too high.

[†] Murray's El. 6 ed. Vol. I. p. 103.

[‡] Because the zero of Fahrenheit's thermometer is 32° lower than that of the centigrade or Réaumur. Before reduction, we must therefore subtract 32° from the Fahrenheit degree, or add it to that of Réaumur, or the centigrade.

[§] See Murray, 2 ed. Vol. I. p. 139. 672° was then admitted as the boiling point of mercury. For other modes of graduation, see Ferg. Lect. Vol. I, p. 181, and Cavallo's Philos. Vol. III, pp. 19, 20.

The thermometer ought therefore to be graduated, when the barometer is at the medium pressure, or a proper allowance should be made for the variation.[*]

(*p.*) *Correspondence of thermometers.*

All thermometers, accurately made upon these principles, will correspond, however different in size or form.[†]

(*q.*) *Choice of fluids.*

Mercury from its mobility, cleanness, beauty, nearly equable expansion by heat, great sensibility to that agent, and the wide difference between its boiling point, +656°[‡] and −39° its freezing point, is generally used;[§] oil is viscid and water very limited in its range, besides its unequal contraction between 40° and 32°.

Alcohol tinged with carmine, is used for intense cold, but cannot be used for heats above 176°,[||] nor quite so high, on account of its unequal expansion near the boiling point; while in sensibility it is much inferior to mercury.

(*r.*) *Imperfections of the thermometer.*

It does not give the result instantly; there is some loss of temperature before the effect can be observed; it gives no information as to the absolute heat, reckoning from the real zero; it indicates only relative heat, or heat compared with some known degree, just as marks may be placed on the links of a chain, whose terminations are concealed. We know not the beginning or the end of heat; but this is not the fault of the thermometer: the range of the thermometer is necessarily limited between the freezing and the boiling points of the fluid with which it is filled.

(*s.*) *Uses of the thermometer.*

No accurate knowledge of the laws of heat could have been obtained without it; hence the observations of the ancients on heat are of little value.

For philosophical purposes, it is indispensable. It is of use to a physician, in observing the phenomena of disease, as of fever and inflammation and in experiments on animal life, &c.

---

[*] See Phil. Trans. 1777, for the rules of the Royal Society; also Phil. Trans. abr. IV. 1. for Newton's rules. See also Martine, on heat and thermometers, and English Jour. Science, Vol. VII. p. 183, Chevalier Landriani.

[†] For various causes of disagreement, see Cordier's Essay on Temp. of the Earth, p. 143.

[‡] This point is stated by Irvine to be 672° of Fahr. (Murray, I. 153.); 662° Petit and Dulong; 656° Crighton, Glasgow; mean of the three, 663½°.—*Hen. 9th ed. Vol. I. p.* 101.

[§] Its boiling point is higher than that of any permanent fluid, and its freezing point lower than that of any fluid, except alcohol and ether. Between 32° and 212°, *its expansion* is almost perfectly uniform, and, although at higher temperatures its expansion goes on in an increasing ratio, glass has, within the above limits, the same ratio, and therefore there is no practical error.—*Turner, p.* 28.

[||] This is its boiling point when its specific gravity is 820, water being 1000.

For medical and chemical purposes, the bulb should be naked, with a part of the tube projecting below the scale.

It has important uses to a gardener, as in observing the temperature in hot houses, and the heat adapted to sowing and planting.

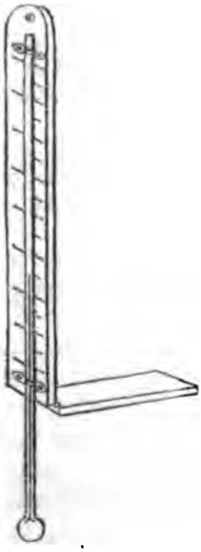
It is useful at sea, as in the gulf stream where the water is warmer than the mean; also in approaching land, and in coming on soundings or shoals, and near icebergs, where the temperature always changes and grows colder.*

It is important to travellers in observing climates; to many artists in regulating their processes, and to all persons in observing the weather, and in regulating the heat in their apartments, in baths, &c.

(*t.*) *Varieties of thermometers.*—The principal are—the self-registering, of which Six's is the most remarkable; the air, the spirit, the water, and the mercurial thermometer. Wollaston's for measuring heights, is a very delicate instrument, which will be mentioned again.

Thermometers are made of various form and graduation, sometimes with glass scales for immersion in acids, with naked balls, &c. They are often in pendent boxes, or in cases which shut for travelling.

Laboratory thermometer.



"The thermometers used in laboratories, are usually constructed so as to have a portion of the wood, or metal, which defends them from injury, and receives the graduation, to move upon a hinge, as in the accompanying figure.

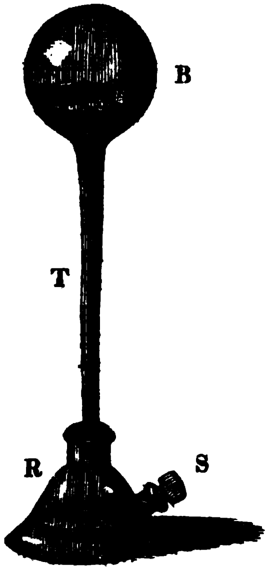
"This enables the operator to plunge the bulb into fluids, without introducing the wood or metal, which would often be detrimental either to the process or to the instrument, if not to both.

"The scale is kept straight, by a little bolt on the back of it, when the thermometer is not in use."—*Dr. Hare.*

---

* The thermometer is regularly used on board of ships of war, and its indications are recorded once or twice a day. Not only does the water always grow colder on coming upon soundings, but generally the air grows colder as we approach land. (See Dr. John Davy's observations in the Journals.)

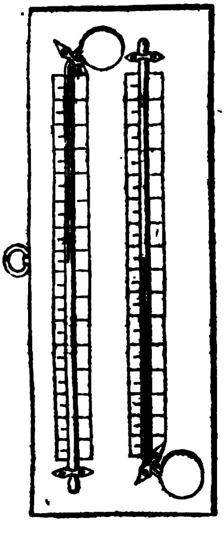
Difference between an air thermometer and a differential thermometer, illustrated upon a large scale.



"The adjoining figure represents an instrument, which acts as an air thermometer, when the stopple S is removed from the tubulure in the conical recipient R; because in that case, whenever the density of the atmosphere varies either from changes in temperature, or barometric pressure, the extent of the alteration will be indicated by an increase or diminution of the space occupied by the air in the bulb B, and of course by a corresponding movement of the liquid in the stem T. But when the stopple is in its place, the air cannot, within either cavity of the instrument, be affected by changes in atmospheric pressure: nor can changes of temperature, which operate equably on both cavities, produce any movement in the liquid which separates them. Hence, under these circumstances, the instrument is competent to act only as a differential thermometer."

Dr. Hare.

Self-registering thermometer.



"This figure represents a self-registering thermometer."

"It comprises necessarily a mercurial and a spirit thermometer, which differ from those ordinarily used, in having their stems horizontal, and their bores round, also large enough to admit a cylinder of enamel, in the bore of the spirit thermometer, and a cylinder of steel, in the bore of the mercurial thermometer. Both the cylinder of enamel and that of steel, must be as nearly of the same diameters with the perforations, in which they are respectively situated, as is consistent with their moving freely, in obedience to gravity, or any gentle impulse."

"In order to prepare the instrument for use, it must be held in such a situation, as that the enamel may subside as near to the end of the alcoholic column as possible, yet still remaining within this liquid."

"The steel must be in contact with the mercury, but not at all merged in it."

"Under these circumstances, if, in consequence of its expansion, by heat, the mercury advance into the tube, the steel moves before it; but should the mercury retire, during the absence of the observer, the steel does not retire with it. Hence, the maximum of temperature, in the interim, is discovered by noting the graduation opposite the end of the cylinder nearest the mercury. The minimum of temperature is registered by the enamel, which retreats with the alcohol when it contracts; but, when it expands, does not advance with it. The enamel must retire with the alcohol, since it lies at its margin, and cannot remain unmoved in the absence of any force competent to extricate it from a liquid, towards which it exercises some attraction. But, when an opposite movement takes place, which does not render its extrication from the liquid necessary, to its being stationary, the enamel does not accompany the alcohol. Hence the minimum of temperature, which may have intervened during the absence of the observer, is discovered, by ascertaining the degree opposite the end of the enamel nearest to the end of the column of alcohol."—*Dr. Hare.*

3. WEDGWOOD'S PYROMETER.

(*a.*) *This instrument is constructed on a different principle from that of other pyrometers and thermometers;* still it affords no exception or contradiction to the law of expansion; it depends on a permanent contraction of certain cylinders of clay in consequence of the application of heat, which operates by expelling water and eventually by causing a chemical union of the alumina and silex of the clay pieces, and an approximation to the condition of porcelain.

(*b.*) *The cylindrical pieces of clay,*[*] are modelled and thrust through a mould, a little flattened on one side—baked gently to expel air and moisture, made to fit at 0 between two converging rules of brass, twenty four inches long, distant at the wider end .5 of an inch, and .3 at the other, and screwed to a brass plate, divided into two hundred and forty equal parts or degrees, each of which is therefore one tenth of an inch.

(*c.*) *Zero of the scale is* 1077½ *of Fahrenheit,* and indicates a full red heat, visible in the day light.

(*d.*) *Each Wedgwood degree corresponds to* 130° *Fahr.*

(*e.*) *To convert Wedgwood degrees into Fahrenheit degrees;* Multiply the Fahrenheit degree by 130 and add 1077.5; thus the two may be compared.

---

[*] The clay used by Mr. Wedgwood, was from Cornwall. See Phil. Trans. Vols. 72, 74, and 76.

(*f.*) *Wedgwood original pieces are not now attainable,*—at least not the same that Mr. Wedgwood used, the bed of clay being exhausted.

Mr. Wedgwood connected his pyrometer with the common thermometer, by the expansion of cylindrical pieces of silver measured in a groove of earthern ware similar to his scale.

Henry states that the greatest degree of heat observed was 185° W. = 25127 Fahr.—*Appendix.*

(*g.*) *Wedgwood's pyrometer is the only one for measuring high furnace heat.*

(*h.*) The highest degree of Wedgwood corresponds to 32.277 Fahr.

(*i.*) The greatest range of observations made by Fahrenheit's thermometer does not exceed the $\frac{1}{32}$ part of that ascertained by Wedgwood.

There is no measure for the highest heat; Dr. Hare's compound blow pipe readily melts all porcelains and other earthy compositions, more refractory than Wedgwood's clay pieces.

(*j.*) *Artificial clay pieces may be made, but little dependence is now placed upon these earthy compositions for pyrometers;* for, Sir J. Hall has ascertained, that a mild heat long continued, has a similar effect in causing them to contract, with a sudden and violent one. Mr. Faraday* considers Daniell's pyrometer as the best.†

II. DISTRIBUTION OF TEMPERATURE AND COMMUNICATION OF HEAT.

1. CALORIC CONSTANTLY TENDS TO AN EQUILIBRIUM.

This tendency is never effectual on a great scale, because of the operation of numerous disturbing causes; the equilibrium is, to a good degree, attainable in a limited and confined space, as in a close room;‡ in such a situation, a thousand bodies of different temperature will ultimately assume nearly or quite the same temperature, and the thermometer, when applied to them severally, ascertains the fact.

(*a.*) *Radiation and actual contact both contribute to the effect.*—At high temperatures, radiation is the most effectual, but actual contact is most efficient at low degrees of heat.

(*b.*) *Caloric radiates through a vacuum.*

Therefore a medium is not necessary to its transmission, a body in a vacuum cools about half as fast as in the air.

2. THE ATMOSPHERE IS VERY UNEQUALLY HEATED.

---

* Chem. Manip. pa. 146.

† See Quarterly Jour. of Sci. XI. 309.

‡ Even in such circumstances there is generally a sensible difference between the temperature of the floor and of the ceiling of the room. See Mr. Marcus Bull's account of his experiments on the heat afforded by different kinds of fuel.

It is most heated at the earth's surface, and in a rapidly decreasing series, (perhaps even a geometrical one,) as we ascend.

(*a.*) *Line of perpetual congelation.*

At a certain elevation in the atmosphere, it freezes in some part of every day in the year; and at a height not less than three miles, it would freeze water, at all times, in every climate, that surrounds our earth.

(*b.*) *Height of the line of perpetual congelation.*

At the equator it is 15577 feet, as ascertained by Mr. Bouguer by actual observation on Pinchinca, one of the peaks of the Andes; in lat. 45° it is 9016 feet; in lat. 70° it is 1557 feet; in lat. 80° it is 120 feet; and at the pole, it is nearly coincident with the earth's surface. Most of these numbers were obtained by calculation, upon a principle explained by Mr. Kirwan.*

(*c.*) *Causes of the increase of cold in the higher regions of the atmosphere.*—The sun's rays do not heat the air while passing through it; they heat the earth first, and this heats the air by actual contact. As we ascend, the capacity of the air for heat increases in an arithmetical, while its density diminishes in a geometrical ratio; hence, it requires more heat to produce a given temperature. Among the minor causes, may be mentioned the absence, in a great degree at high elevations, of animal and vegetable life, of fermentation, of combustion, respiration and putrefaction, all of which generate heat.

(*d.*) *Snow is in every climate, perpetual on high mountains.*—Because their tops pierce the regions of perpetual cold, and snow once remaining the year round, will continue; the sun cannot, in a second summer, melt what it has failed to melt in a first.

Any commencement of warming there, by the sun's rays, before the first snow fell, would have been very transient, because ventilation would soon begin, as the lateral columns of air, not over the mountain ridges or top, would not be heated at that elevation, and being heavier would rush in upon them on all sides, and therefore the surface there would never become warm.

(*e.*) *Effect of the winds on the term of perpetual cold.*

They raise it by mingling warm air with the cold; if there were no winds, perpetual cold would no where, be over a mile above the earth's surface.—*Dr. Black's Lectures.*

---

* The mean temperature at the equator and in any parallel of latitude, being ascertained by observation, we take the difference between each of these two numbers and the freezing point; the height of the term of perpetual congelation at the equator is also ascertained by observation; the number to be found, is the height of the same term in any parallel of latitude; the proportion will be, as 52° (84° mean temp.—32° = 52) the number at the equator, is to 15.577 the height of the term of perpetual congelation there, so is 40°.3 the number at 28° of lat. (72°.3 mean temp. —32° = 40°.3 = third term,) to 12.072 the height of the term of congelation there, and so for any other latitude. Due allowance must of course be made, for the elevation of the country above the sea, for its mountainous or level surface and for various other causes, which would influence its climate.

It results therefore, from all our knowledge, that our atmosphere is, throughout its whole extent, in every climate, and in every season, a region of unmitigated cold, excepting the small spheroidal portion which is nearest to the earth—distant from it less than three miles in the torrid climates; rapidly approaching the earth in the other climates, and almost touching it at the poles. Therefore, between the planets and in space generally,* it is probable, that the temperature is very low.

3. COMMUNICATION OF HEAT—CONDUCTION, RADIATION.

A. The name of CONDUCTION is given to the slow passage of Caloric through the substance of bodies and to its cause; that of RADIATION, to the instantaneous passage, from surfaces, and through a transparent medium, and also to the cause of it.

(b.) *The conducting powers of bodies are widely different.*—If a cylinder of metal and one of glass, of the same size, be held by the fingers in the fire, the metal will feel hot, and perhaps become intolerable to the touch, while the glass will communicate little or no heat.

Those bodies which in their ordinary state feel coldest to the touch, are the best conductors, and vice versa; hence, some bodies are supposed to be naturally cold, as for instance, marble; others naturally warm, as woollen; but this is an error. They may have the same temperature by the thermometer, and still impart very different sensations, as will be perceived by laying one hand on fire brick and the other on trap† rock; or more strikingly, one hand on woollen, and the other on metal, both being of the same temperature by the thermometer.

When we apply the hand to various objects in our apartment—"the carpet will feel nearly as warm as our body; our book will feel cold, the table cold, the marble chimney piece colder, and the candlestick colder still, yet, a thermometer applied to them will stand in all at nearly the same elevation. They are all colder than the hand; but those that carry away caloric most rapidly, excite the strongest sensations of cold."‡

(c.) *Bodies, taken in classes, conduct better, the more dense they are, and vice versa.*

Metals conduct better than any other bodies, but there is a difference among them, for instance, copper and tin conduct better than lead and platina.

The following metals conduct heat, nearly in the order in which they are named.

Silver, Gold, Copper, Tin,—nearly equal.

Platina, Iron, Steel, Lead,—much inferior to the others.

(d.) *Bodies conduct heat worse, the more spongy and divided their parts are.*

---

* Except perhaps near the innumerable suns.

† Or any stone;—trap is here mentioned, because it is a very good conductor of its class.

‡ Turner's Chemistry, pa. 11, first Edition.

Iron filings are worse conductors than an iron bar of the same weight; saw dust is worse than the solid wood.—*Rumford*. The cause probably is the intervention of air between their parts; air being a very bad conductor.

(*e.*) *Stones are next to metals.*

Crystalline stones conduct better than mechanical aggregates, e. g. trap better than sandstone; the difference is evident to the touch, and it appears also, from their widely different power of condensing the atmospherical vapor; a trap rock will be wet from this cause, while one of sandstone will be dry.

Earth and sand conduct worse than stones. At the siege of Gibraltar, in the American war, red hot balls were carried from the furnaces to the bastions, in wooden wheelbarrows, by merely placing a layer of sand beneath them.

(*f.*) *Bricks are worse conductors than stones.*

Because they are full of pores containing air; they are used to impede the escape of heat, as in the lining of chemical furnaces of iron,* which, while they are melting brass or cast iron within, can be safely touched by the hand without.

A hot brick or plank, wrapped in flannel, retains its heat a long time; it is used for warming the feet, in winter travelling, and in sickness.

(*g.*) *Glass is a very bad conductor.*

When thick, it cracks from sudden heating or cooling, but, if thin, it bears sudden changes of temperature very well. The reason is, that being a bad conductor, when one side is hot, it swells, and the colder side is strained, and often gives way.

(*h.*) *Dry wood is a bad conductor.*

Hence, it is used for handles of metallic instruments, as of ladles, soldering irons, tea and coffee pots, gridirons,† &c. It is also a bad conductor of electricity. "Common bone, whale bone, ivory and porcelain," are very imperfect conductors, especially when compared with metals.

(*i.*) *Charcoal is a very bad conductor.*—It may be held by the fingers, within an inch or less, of the part which is red hot; it is used in wine coolers, with double sides, to prevent the entrance of heat, and it is mixed with clay and other materials for bricks and crucibles.

(*j.*) *Feathers, silk, wool, hair, and down, are still worse conductors.*—Hence they are so effectual in preserving animal heat, both in the animals naturally invested with them, and in the human race who wear them for clothes. They are not naturally warm, but preserve our animal heat from escaping. Loose garments are warmer than those that are tight, because they imprison the air, and the same weight of clothing, in two or more thicknesses, is warmer than in one; hence the advantage of lining and quilting, as in comfortables,[*] down coverlets, &c.

---

* And in the iron furnaces now used in this country, for burning anthracite coal.

† Worsted, being a very bad conductor, workmen who have occasion to handle substances which are either hotter or colder than is agreeable, frequently wear gloves made of this substance.—L. U. K.

At Wallingford, Con. pewter tea pots are now made, with hollow metallic handles, and they do not often become inconveniently hot, because they contain imprisoned air.

The finer the fibres, the more effectual they are; therefore animals are provided with fur which is finest in the coldest countries, and in winter it is finer than in summer; in aquatic birds and amphibia, the fur and feathers are finer than in the terrestrial races. Fine wooled sheep would, in torrid climates, become coarse wooled. Some covering of this nature is necessary even in hot climates, to protect animals from the copious dews and rains, and other atmospherical changes.

(*k.*) *Ice is a bad conductor and snow still worse.*—Hence ice retards the congelation of the water below; snow protects the grass and grain from destruction by severe cold; it differs from ice because it imprisons air in its cavities. When the air in Siberia was — 70°, the earth under the snow was only 32°. Snow huts or holes so often used by travellers in cold countries, as in the north western regions of America,[†] are very warm.

(L.) FLUIDS[‡] ARE WORSE CONDUCTORS THAN ANY SOLIDS.

The common impressions on this subject are erroneous; fluids are usually heated at bottom, and the change of specific gravity throws them into currents; warm currents flow upward and cold downward, and thus the heat is soon diffused. "If a thermometer be placed at the bottom and another at the top of a tall jar, the heat being applied below, the upper one will begin to rise almost as soon as the lower."—*Turner.*

Heat, applied at the surface, travels downward very slowly. Mr. Murray provided a cylindrical vessel of ice;[§] he froze a thermometer in at right angles to the side, and near the top, filled the vessel with oil and applied heat on the surface; there was no conducting power in the sides,[||] but the thermometer proved that the heat did travel down, although with extreme tardiness: therefore fluids are not *non* conductors, but only very bad conductors.

In solids, the particles are stationary or only recede from each other, and the heat travels; in fluids, their own particles travel and transport the heat.

(M.) GASES, AIR, VAPORS, AND ALL AERIFORM FLUIDS, ARE THE WORST CONDUCTORS KNOWN.

---

[*] A name given in this country, to a bed covering made in the manner described in the text. [†] Captain Parry, and Am. Jour. Vol. XIII, p. 391.

[‡] Except mercury and melted metals generally.

[§] Nicholson's Journal, 8vo. Series, Vol. I, p. 241.

[||] Ice is a conductor, although a bad one, at all temperatures below 32°; as it melts at that degree, it follows that in this experiment, any heat derived from the hot fluid, would go only to melt the ice, but would not travel down its sides.

Here again the common impressions are erroneous. Air is commonly used to *cool* bodies, but it is air in motion, not air at rest. Air *in motion* cools hot bodies rapidly, because new particles come every moment into contact with the heated body. Air confined, impedes the progress of heat more than any other body, because it is among the very worst of conductors.

Double windows, double walls, furred* walls, all contribute very much to keep houses warm in winter and cool in summer, because the parallel surfaces imprison the air between them.

(*n.*) *Change of temperature instantly disturbs the statical pressure of the air and produces currents.*—A common fire, a lamp, a candle, and all furnaces, are examples.

When the fire is active, there are opposite currents in a warm room, of cold air along the floor, and of warm air along the ceiling. The currents divide at an open door; hot air passes out above, and cold air blows in below, as may be seen by placing the flame of a candle in the door; above, it will point outward; below, inward, and at an intermediate point, it will be perpendicular; or, three candles may be used at the same time, and the effects will be as stated above: the hotter the room and the colder the external air, the more striking will be the effect.

(*o.*) *The best air for respiration is usually along the floor.*—People falling from suffocation, in bad air, often recover on reaching the floor; a principal, although not perhaps the sole reason, is, because the deadly gases and vapors, if not *specifically* lighter than air, are usually *temporarily* so from their rarefaction, as they are commonly produced either by respiration† or combustion. A life preserver used in fires, is worn on the head, and a projecting flexible tube descends like an elephant's proboscis, so that the orifice or snout touches the floor, and thus the wearer breathes, it may be, tolerable air, while that which surrounds his head, would, if inspired, be noxious or perhaps fatal.

(*p.*) *The current of a chimney and of common winds, as well as monsoons, trade winds, and even hurricanes and tornados, depends on the ascent of air rarefied by heat.*—Warm air, that is to say, lighter air is forced upward by colder, or in other words, by heavier air.

The monsoons of India are produced by the heating of the earth, and consequently of the air, by the sun, during his visit to the northern tropic: the colder air, from the ocean consequently rushes in to restore the equilibrium: during his passage to the southern tropic, the process is reversed, and the wind blows, for six months, the other way.

---

* *Furred*, a term applied by the builders to an interior wall in a stone or brick house, laid not upon the solid material, but upon lath, which are nailed to perpendicular strips of boards or plank, and these again to billets of wood laid in the masonry; there is then a space filled with imprisoned air.

† In bed rooms, especially in cold weather, carbonic acid gas, flowing rarefied from a hot source, may afterwards become so chilled, as to fall and prevail most near the floor; a pan of coals or even a lamp or a candle may in this manner, especially in a small room, without an open chimney, produce a noxious atmosphere.

Sea breezes by day, and by night, in hot climates, and in hot weather in temperate climates, depend upon the same principle. The trade winds are caused by the tendency of the cold currents to restore the pressure, occasioned by the rarefaction of the air, within the tropics, from the perpetual presence of the sun in that region. Hence, the currents which the atmosphere pushes in, from the north east and the south east, are, at the equator, blended into one, which follows the apparent course of the sun. The heated air which rises, is in the mean time diffused over the upper regions of the atmosphere, flows north and south, is chilled and condensed, and falls in the temperate and polar regions, to go through the same round again.*

(*q.*) *Currents upward and downward, both in gross and aerial fluids, produce a vast and salutary effect on the comfort of the globe.*

The warm ocean imparts its heat to the chilled land, of the polar regions, and the hot land of the tropical countries gives its heat to the water of the cool ocean; the monsoons and trade winds and common winds produce a similar effect in the atmosphere.†

Without currents, the atmosphere would become fatally hot, in torrid, and fatally cold in frigid climates; and similar inequalities in the ocean and other great waters would be deadly to the aquatic animals.

(R.) RADIATION OF HEAT IS ITS (*apparently*) INSTANTANEOUS PASSAGE THROUGH TRANSPARENT MEDIA.

We can *perceive* no progress, and therefore regard the passage as instantaneous: there can be no reasonable doubt that it passes as rapidly as light.

(*s.*) *Caloric or heat radiates from the sun, from fires, and volcanos, and probably from all bodies.*—All our experience confirms this statement, and particular experiments to prove it will be mentioned hereafter.

(*t.*) *Solar heat radiates more or less, through all transparent media, whether solid, fluid or aerial,* and generally without heating them materially.‡

(*u.*) *Culinary, or artificial heat radiates only through air, and other aerial fluids, and not through transparent solids, or transparent gross fluids, as water, alcohol, &c.*—The cause of this difference is not known.

(*v.*) *The transparent bodies through which artificial heat does not*

---

* See Dr. Hare's essay on the gales of the Atlantic States of N. Am. Am. Jour. Vol. V, p. 352.

† Murray, 2d Edit. Vol. I, p. 276.

‡ The lower regions of the air would be quite as cold as the upper, did they not receive heat from the earth.

§ There is a difference in this respect, among media; water arrests about half the rays, and alcohol more than half, and of course heat is acquired by these fluids.

radiate are heated by it, but they derive little heat from the solar rays, which permeate them easily.

For the most important facts respecting the radiation of heat, see the section on the nature of heat and light.

A few facts may be added here.

(*w.*) *Polished surfaces, of all bodies that are not transparent, reflect radiant solar heat*, and do not transmit it.*

(*x.*) *Caloric not only radiates freely in a vacuum,*† *but it is not impeded by currents or agitation of the air.*—Winds do not disturb sunshine, and the solar focus is equally distinct and powerful, in a windy as in a still day. Bellows blowing across a current of radiant culinary heat, do not divert the rays.

(Y.) *Surface has a great effect on the radiation and reception of heat independently of the nature of the material.*

Black‡ and rough surfaces, radiate and receive heat the best; bright and polished surfaces, the worst. Glass, however, although naturally polished, radiates and receives heat very well, and so do paper, skin, and animal membrane; the latter radiates and receives twenty five times as powerfully as polished metal.

(*z.*) *The radiating and absorbing powers are alike and equal; but the radiating and reflecting powers are directly opposed, and are inversely as each other.*—In a cubical vessel of tin, one of whose sides was blackened, another papered, and another glazed, the radiation was in the following proportion—

from the black side, - - -	100°	
" " papered, - - - - -	98°	
" " glazed, - - - - -	90°	
" " bright metallic, - - -	12°	*Leslie.*

(*aa.*) *The thermometer indicates more or less of heat, according as its surface is blackened, covered with tin foil or other good reflector, or is in its natural state.*—For a comparative result, it should be at the same temperature in the beginning of different experiments.

(*bb.*) *All mirrors lose their power of reflecting heat if blackened—and become heated.*—Glass mirrors, not reflecting culinary heat, do reflect it, if covered with tin foil.

---

* In order that this should be strictly true, the solids must be supposed to be *perfectly* smooth, of which we have perhaps no examples. Scratched metallic surfaces receive and emit more heat, if the scratches cross one another, than if they are parallel; the difference is attributed to the formation of points, by the intersection, through which points, the heat more readily passes.

† As ascertained by Pictet and Rumford. In the experiments of the latter it pervaded the Torricellian vacuum. Sir Humphrey Davy found that a thermometer was heated by radiation, from charcoal, ignited by galvanism in a vacuum, three times as much as it would have been in the air; there being no cooling effect from currents.

‡ Dr. Turner doubts whether color has any effect on the absorption of heat unless the latter is accompanied by light, in which case he calls it luminous caloric: but then he allows that the effect is great.

PRACTICAL QUESTIONS.

(*cc.*) *Why are black* clothes hotter in the summer and in the sun, than in the winter and in the shade?*—In order to settle this question, it is necessary to ask another, that is, in what circumstances will the absorption exceed the radiation of heat? This will plainly be in the summer, and the reverse will be true in the winter.

(*dd.*) *Why do black people endure heat better, and cold worse, than white people?*—The answer depends on the same cause, taking into view the average animal temperature.

(*ee.*) *Why should steam, which we wish not to condense, be conveyed in bright tubes, and vice versa?*—Because such surfaces radiate heat badly.

(*ff.*) *Why does a common rolled iron stove pipe diffuse heat better than a bright tinned one?*—Because its surface is rough, and therefore radiates heat powerfully.†

(*gg.*) *Why does water keep hot longer in a bright polished vessel than in a dark and rough one?*‡—The answer is the same as in *ee.*

(*hh.*) *Why does water become heated rapidly in a rough iron kettle, and slowly or not at all in one of bright copper?*—The answer is the same as in *ff*, reception being substituted for radiation.

(*ii.*) *Why would an earthern ware tube, when gilded, preserve steam longer uncondensed, than the same tube with its natural surface, or than bright tinned iron?*—Because the substance is a bad conductor, and the surface a bad radiator.

(*jj.*) *Why does snow melt rapidly where the dirt is thrown upon or mixed with it, as in the travelled path, and slowly, or not at all,*

---

* Quere, (communicated—)" Are black clothes, when worn in the *shade* during summer, warmer or cooler than white clothes in the same circumstances?" The answer will depend on the radiating and receiving power of the surfaces, and on the temperature of the air, compared with that of the body.

† In neither of these cases, is the final cause assigned; it is unknown.

‡ Experiment in Yale College Laboratory, Nov. 10th. 1826.—A blackened and a polished canister of plated tin of the same form and size, being filled with water at 200°—their times of cooling were as follows.

Blackened Canister cooled		Polished Canister cooled		Dif.	Accumulating differences.
in the 1st 12 minutes,	10°	in the 1st 12 minutes,	6°	4°	4°
" " 2d 12 "	8	" " 2d 12 "	5	3	7
" " 3d 12 "	7	" " 3d 12 "	5	2	9
" " 4th 12 "	6	" " 4th 12 "	3	3	12
" " 5th 12 "	8	" " 5th 12 "	3	5	17
" " 6th 12 "	9	" " 6th 12 "	5	4	21
" " 7th 12 "	8	" " 7th 12 "	5	3	24
" " 8th 12 "	5	" " 8th 12 "	3	2	26
96 min.	61°	96 min.	35°		

In one hour and thirty six minutes, the *blackened canister* cooled 61°, during which time the *polished one* cooled but 35°. (At two hours from the completion of the above experiments, viz. three hours and thirty six minutes from the commencement, the water in the polished canister was still 20° warmer than in the blackened one.)

where it is clean, and especially if glazed, by frozen rain?—Because snow is a good reflector, and dirt, from its rough dark surface, absorbs heat rapidly.

(*kk.*) *Why on copper plates painted black, white, gray, &c. does wax melt soonest on the black and other dark colors, and scarcely at all on the white,* when they are exposed to the sun?*—The answer is founded on the general effect of colors on the absorption and radiation of heat.

(*ll.*) *Why do pieces of cloth of different colors, black, white, and intermediate shades, when laid on snow in the sunshine, sink into the snow very differently, the black deepest, and the white not at all?*—The answer is the same as under *kk.*

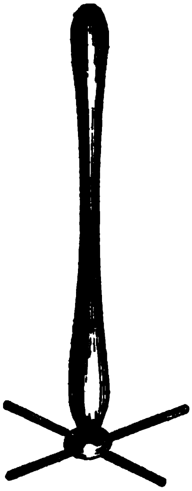
(*mm.*) *Why in summer, is the temperature of the earth several degrees lower than that of the air, especially in a clear night?*—It is owing chiefly to radiation, as beautifully illustrated by Dr. Wells.

(*nn.*) *Why, in hot weather, is a house cooler if kept dark, than if light and air are freely admitted?*—Because the radiant heat, flowing, not from the sun only, but from all external objects, some of which are often much heated, is also excluded.

(*oo.*) *Why is white a good color for the roof of an ice house, and black a bad color for any roof?*—Because the former reflects, and the latter absorbs the heat rapidly.

EXPERIMENTAL ILLUSTRATIONS.

1. *Inequality of conducting power.—Dr. Hare, from* 1 *to* 11, *except* 3, 4, *and* 8.

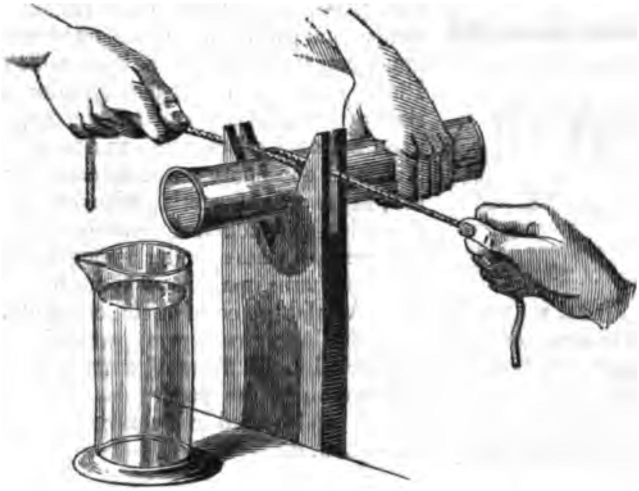


"Let there be four rods, severally of metal, wood, glass, whale bone, each cemented at one end to a ball of sealing wax. Let each rod, at the end which is not cemented to the wax, be successively exposed to the flame excited by a blow pipe. It will be found, that the metal becomes quickly heated throughout, so as to fall off from the wax—but, that the wood, or whalebone, may be destroyed, and the glass bent, by the ignition, very near to the wax, without melting it, so as to liberate them."

---

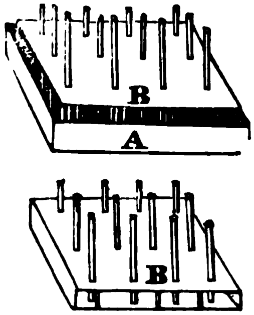
* The colored surfaces receiving the rays, and the waxed side being downwards.

2. Glass so heated by the friction of a cord, as to separate into two parts, on being subjected to cold water.



"Some years ago, Mr. Lukens showed me, that a small phial, or tube, might be separated into two parts, if subjected to cold water, after being heated by the friction of a cord made to circulate about it by two persons alternately pulling in opposite directions. I was subsequently enabled to employ this process, in dividing large vessels, of four or five inches in diameter, and likewise to render it, in every case more easy, and certain, by means of a piece of plank forked like a boot jack—as represented in the preceding figure—and also having a kerf, or slit, cut by a saw, parallel to, and nearly equi-distant from, the principal surfaces of the plank, and at right angles to the other incisions."

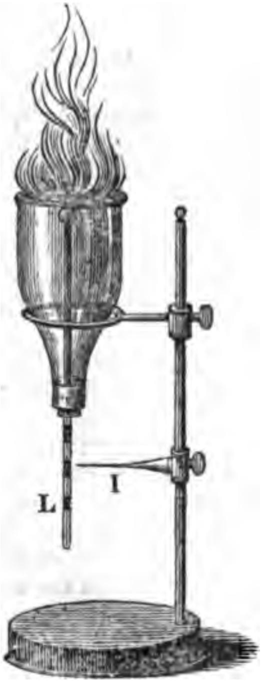
"By means of the fork, the glass is easily held steady by the hand of one operator. By means of the kerf, the string, while circulating about the glass, is confined to the part, where the separation is desired. As soon as the cord smokes, the glass is plunged into water, or if too large to be easily immersed, the water must be thrown upon it. This method is always preferable when the glass vessel is so open, that on being immersed, the water can reach the inner surface. As plunging is the most effectual method of employing the water, in the case of a tube, I usually close the end which is to be sunk in the water, so as to restrict the cooling to the outside."



A, is the iron basin and B, the apparatus described above.

3. **Metals, &c.**—Provide as many equal cylinders of metals as may be desired; fix them vertically in a perforated copper or iron plate, their lower ends resting on a similar and parallel plate connected with the upper one at a small distance by metallic posts. Place upon each metallic cylinder a thin slice of phosphorus, and set the apparatus upon hot sand contained in an iron pan; the pieces of phosphorus will successively take fire, in the order (cæteris paribus) corresponding with the conducting power of the metals. If there be a glass cylinder among the others, the phosphorus upon that will not take fire.*

4. **Metals and Wood.**—A solid piece of metal one and a half inches in diameter, and eight inches long, closely wrapped in clean writing paper, will bear to be immersed in the flame of a spirit lamp, for a considerable time, without scorching the paper; but if the paper be applied to a piece of wood, and heated in a similar manner, the paper will immediately burn.—L. U. K.



5. *Liquids almost destitute of conducting power.*

That liquids are almost devoid of power to conduct heat is proved by the inflammation of Ether, over the bulb of an air thermometer, protected only by a thin stratum of water.

"The inflammation of ether, upon the surface of water, as represented in this figure, does not cause any movement in the liquid included in the bore of the thermometer at L, although the bulb is within a quarter of an inch of the flame. Yet the thermometer may be so sensitive, that touching the bulb, while under water, with the fingers, may cause a very perceptible indication of increased temperature."

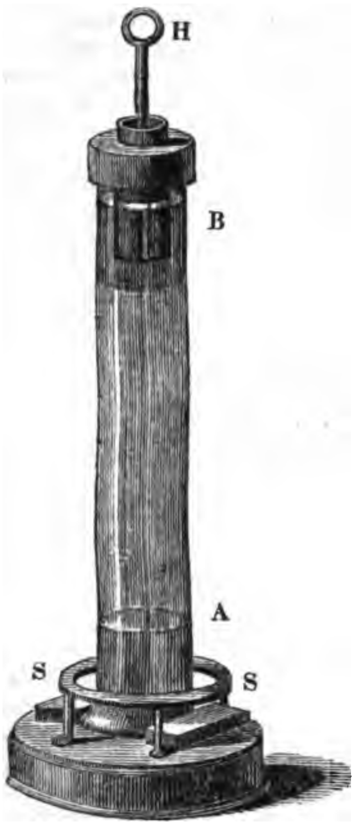
"By placing the sliding index I, directly opposite the end of the liquid column in the stem of the thermometer, before the ether is inflamed, it may be accurately discovered whether the heat of the flame causes any movement in the liquid."

---

* Sometimes the phosphorus will melt in the air, without taking fire, but on jarring the apparatus, it will blaze; a thin film of oxidized phosphorus apparently protects the phosphorus below from combustion.

CIRCULATION INDISPENSABLE, TO AN EFFECTUAL COMMUNICATION OF HEAT IN LIQUIDS.

6. *Different effects of heat on the upper or lower strata of a liquid.*



"A glass jar, about 30 inches in height, is supplied with as much water as will rise in it within a few inches of the brim. By means of a tube* descending to the bottom, a small quantity of blue coloring matter is introduced below the colorless water, so as to form a stratum as represented at A, in the engraving. A stratum, differently colored, is formed in the upper part of the vessel, as represented at B. A tin cap, supporting a hollow tin cylinder, closed at bottom, and about an inch less in diameter than the jar, is next placed as it is seen in the drawing, so that the cylinder may be concentric with the jar, and descend about 3 or 4 inches into the water."

"The apparatus being thus prepared, if an iron heater, H, while red hot, be placed within the tin cylinder, the colored water, about it, soon boils; but the heat penetrates only a very small distance below the tin cylinder, so that the colorless water, and the colored stratum, at the bottom of the vessel, remain undisturbed, and do not mingle. But if the ring, R, be placed, while red hot, upon the iron

stand which surrounds the jar at S S, the portion of the liquid, colored blue, being opposite to the ring, will rise until it encounters the warmer, and of course lighter particles, which have been in contact with the tin cylinder. Here its progress upwards is arrested; and in consequence of the diversity of the colors, a well defined line of separation is soon visible.*"

---

* e. g. A dropping tube.

"The phenomena of this interesting experiment may be thus explained."

"If the upper portion of a vessel, containing a fluid, be heated exclusively, the neighboring particles of the fluid, being rendered lighter, by expansion, are more indisposed, than before, to descend from their position. But, if the particles, forming the inferior strata of the fluid in the same vessel, be rendered warmer than those above them, their consequent expansion and diminution of specific gravity, causes them to give place to particles above them, which, not being as warm, are heavier. Hence, heat must be applied principally to the lower part of a vessel, in order to occasion a uniform rise of temperature in a contained fluid."

"This statement is equally true, whether the fluid be aëriform, or a liquid, excepting that in the case of aëriform fluids, the influence of pressure on their elasticity, may sometimes co-operate with, and at others oppose, the influence of temperature."

7. *Process by which caloric is distributed in a liquid before it boils.*

"On the first application of heat to the bottom of a vessel containing cold water, the particles in contact with the bottom are heated and expanded, and consequently become lighter in proportion to their bulk, than those above them. They rise therefore, giving an opportunity to other particles to be heated, and to rise in their turn. The particles which were first heated, are soon, comparatively, colder than those by which they were displaced, and, descending to their primitive situation, are again made to rise, by additional heat, and enlargement of their bulk. Thus the temperatures reversing the situations, and the situations the temperatures, an incessant circulation is supported, so long as any one portion of the liquid is cooler than another; or in other words, till the water boils; previously to which, every particle must have combined with as much caloric, as it can receive, without being converted into steam."

---

* "I used to perform this experiment with an inclined tube, as suggested in Henry's Chemistry. The modification here given, is so far a contrivance of my own, as relates to the use of the heater, tin cap, and iron ring; and the employment of two colors instead of one. On account of the liability of the glass to crack, I found the old method very precarious, when a tube was used large enough to show the phenomena advantageously."

"The manner in which caloric is distributed throughout liquids by circulation, as above described, is illustrated advantageously by an experiment contrived by Rumford, who first gave to the process, the attention which it deserves."

"Into a glass nearly full of water, as represented by the foregoing figure, some small pieces of amber are introduced, which are in specific gravity so nearly equal to water, as to be little influenced by gravitation."

"The lowermost part of the vessel being subjected to heat, while thus prepared, the pieces of amber are seen rising vertically in its axis, and after they reach the surface of the liquid, moving towards the sides, where the vessel is colder from the influence of the external air. Having reached the sides of the vessel, they sink to the bottom, whence they are again made to rise as before. While one set of the fragments of amber, is at the bottom of the liquid, some are at the top, and others at intermediate situations; thus demonstrating the movements, by which an equalization of temperature is accomplished in liquids."

"When the boiling point is almost attained, the particles being nearly of one temperature, the circulation is retarded. Under these circumstances, the portions of the liquid which are in contact with the heated surface of the boiler, are converted into steam, before they can be succeeded by others; but the steam thus produced, cannot rise far before it is condensed. Hence the vibration and singing, which is at this time observed."

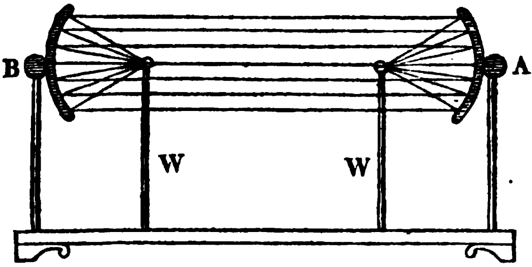
8. Provide a glass tube twelve or fifteen inches long and from two to two and a half wide, closed at one end, and that end thin, so as to bear heat; nearly fill the tube with alcohol, and then with a dropping tube, convey to the bottom some alcohol, colored by turmeric or cochineal and rendered a little heavier by water; if dexterously done, there will be a well defined line of separation; then apply heat at the bottom, and the color will be rapidly diffused.

Now repeat the experiment, only place the colored alcohol* on the surface; the color on the top will be scarcely disturbed till the fluid begins to boil.

---

* It is hardly necessary to say, that no water should be added to it.

9. *Model for illustrating the operation of concave mirrors.*



"The object of the model represented by this diagram, is to explain the mode in which two mirrors operate, in collecting the rays of radiant heat emitted from one focus, and in concentrating them in another."

"The caloric emitted by a heated body in the focus of the mirror A, would pass off in radii or rays lessening their intensity, as the space into which they pass enlarges; or, in other words, as the squares of the distances. But those rays which are arrested by the mirror, are reflected from it in directions parallel to its axis.* Being thus corrected, of their divergency, they may be received, without any other loss, than such as arises from mechanical imperfections, by the other mirror; which should be so placed, that the axes of the two mirrors may be coincident; or, in other words, so that a line drawn through their centres, from A to B, may at the same time pass through their foci, represented by the little balls supported by the wires, W W."

"The second mirror, B, reflects to its focus, the rays which reach it from the first; for it is the property of a mirror, duly concave, to render parallel the divergent rays received from its focus,—and to cause the parallel rays which it intercepts, to become convergent, so as to meet in its focus."

"The strings, in the model, are intended to represent the paths, in which the rays move, whether divergent, parallel, or convergent."

10. *Phosphorus*† *kindled at the distance of twenty, or even at sixty feet, by an incandescent iron ball.—Dr. Hare.*

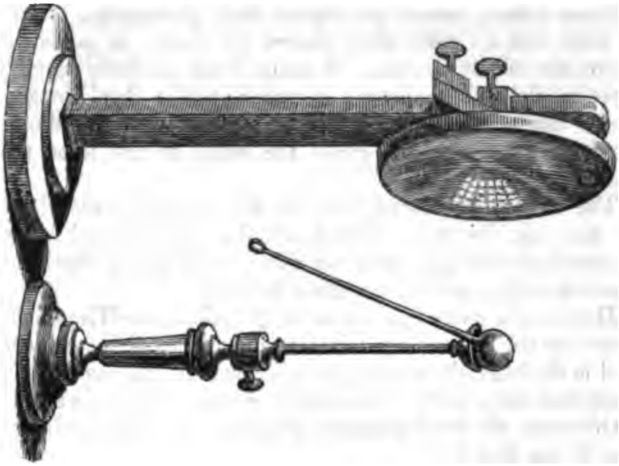
"The annexed figure represents the mirrors, which I employ in the ignition of phosphorus, and lighting a candle, by an incandescent iron ball at the distance of about twenty feet."

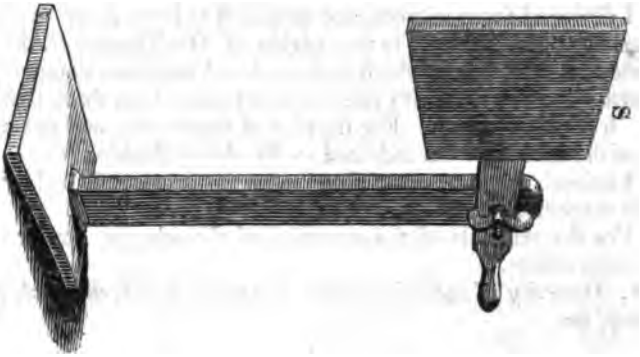
"I have produced this result at sixty feet, and it might be always effected at that distance, were it not for the difficulty of adjusting the foci with sufficient accuracy and expedition. I once ascertained that a mercurial thermometer, when at the distance last mentioned, was raised to 110 degrees of Fahrenheit."

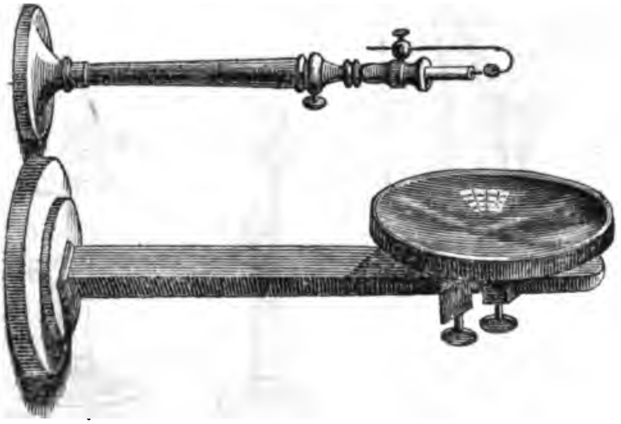
---

* "The axis of a mirror is in a line drawn from its centre through its focus."

† Especially if enveloped in cotton, which is a bad conductor.







"Some cotton, imbued previously with phosphorus, is supported by a wire over a candle wick, placed as nearly as possible, in the focus of one of the mirrors. A lamp being similarly situated with respect to the other mirror; by receiving the focal image of the flame on any small screen, it will be seen in what way the arrangement must be altered to cause this image to fall upon the phosphorus."

"The screen S, placed between the mirrors, is then lowered so as to intercept the rays. The iron ball being rendered white hot, is now substituted for the lamp, and the screen being lifted, the phosphorus takes fire, and the candle is lighted."

"*Description and construction of the mirrors.*—The mirrors represented by the figure, are sixteen inches in diameter, and were turned in the lathe, the cutting tool being attached to one end of an iron bar two feet long, which at the other end turned upon a fixed pivot."

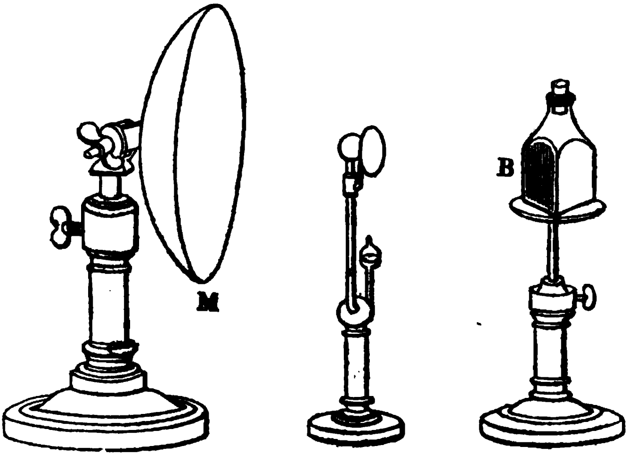
"Of course the focal distance, being one half the radius of concavity, is one foot."

"I designed these mirrors, and proposed to have them made out of castings; but pursuant to the advice of Dr. Thomas P. Jones, I resorted to sheet brass, which was rendered the more competent by strengthening the rims with rings of cast brass, about three fourths of an inch thick each way. For the idea of these rings, and the execution of the mirrors, I am indebted to Mr. Jacob Perkins."

"I believe there are none superior, as the face is reflected by them much magnified, but without the slightest distortion."

"For the rationale of the operation of the mirrors, I refer to the preceding article."

11. *Diversity of radiating power in metals, wood, charcoal, glass, pottery, &c.*



"At M, in the preceding figure, a parabolic mirror is represented. At B, a square glass bottle, one side of which is covered with tinfoil, and another so smoked by means of a lamp, as to be covered with carbon. Between the bottle and mirror, and in the focus of the latter, there is a bulb of a differential thermometer, protected from receiving any rays directly from the bottle, by a small metallic disk. The bottle being filled with boiling water, it will be found that the temperature in the focus, as indicated by the thermometer, is greatest when the blackened surface is opposite to the mirror; and least, when the tinfoil is so situated; the effect of the naked glass being greater than the one, and less than the other."

"When a polished brass andiron is exposed from morning till night to a fire, so near as that the hand, placed on it, is scorched intolerably in a few seconds, it does not grow hot."*

"Fire places should be constructed of a form and materials to favor radiation: flues, of materials to favor the conducting process."—

12. A cork thrust into a candlestick; some black wool pushed by a knife into a slit in the cork; some thin slices of phosphorus or sulphuret of phosphorus, laid upon the wool or wrapped in it, the focus being previously ascertained by the light of a candle, will hardly ever fail of success,† an ignited iron ball or a few live coals being placed in the other focus. A screen of glass or metal may be held between the mirrors till we are ready for the result.

13. Fulminating mercury, or silver, or gunpowder, may be sprinkled on the wool or on charcoal, but they will by their explosion soil the mirror: the effect is otherwise agreeable.

14. Boiling water being in one focus and a delicate air, or differential thermometer in the other, there is an evident movement of the fluid, and the glass screen being interposed, arrests and soon reverses the effect.

15. A bright metallic mirror, held before a common fire, remains cold, but, if blackened by candle smoke or India ink, it becomes hot.

16. Provide two bright tin flasks or polished metallic tea pots; blacken one with candle or lamp smoke, then pour boiling hot water from a tea kettle into both; examine the temperature, at intervals of five minutes, and it will be found that for more than an hour, the bright vessel will remain decidedly the hottest, and sensibly so for several hours.‡

17. Fill them with cold water and place them before a bright fire; the blackened vessel will become hot, and the other will remain cold.

---

* Except that a little heat passes by slow communication along the iron bar.

† A mouse trap without the bottom, supported by the ring of a retort stand, makes a good fire grate, and a sheet of copper, zinc, or iron, will protect the table from the falling coals.

‡ See the statement of experiments, page 71.

With a mask coated with tin foil, our faces may safely encounter the blaze of a glass house furnace.—*Ure's Dic.* 277.

18. Hot water cools faster in a glass, than in a polished metallic vessel.

19. "*Radiation of cold.*—A thermometer, placed in the focus of a mirror, indicates a decline of temperature, in consequence of a mass of ice or snow being placed before it, in the situation occupied by the bottle, in the preceding figure. This change of temperature has been ascribed to the radiation of cold, and has been considered as demonstrating the materiality of that principle. For, since the transfer of heat, by radiation, has been adduced as a proof of the existence of a material cause of heat; it is alleged that the transmission of cold, by the same process, ought to be admitted in evidence, of a material cause of cold."*

But, it is necessary to suppose only that the heat flows from the thermometer, which is relatively the hotter body, to the ice, which is constantly absorbing the radiant heat of the room and that of the thermometer more than of any other body, because the heat is there concentrated by the mirrors, and thence flows in greater quantities than is true of any other place.†

III. Congelation and Liquefaction.

(*a.*) *Dr. Black first proved that fluidity depends on a peculiar combination or operation of heat or caloric.*

(*b.*) *The sensible heat of both melting ice and freezing water is at all times and places* 32° *of Fahr.*‡—h.

The water, when first formed by melting, is at 32°, and the heat absorbed during liquefaction has merely melted the ice, and has not raised its temperature. If ice is colder than 32°, it cannot melt till it attains that temperature, and the sensible heat will neither rise nor fall during the process of melting.

(*c.*) *The quantity absorbed is* 140°—A pound of snow at 32° and a pound of water at 172°, if quickly mingled, will give the temperature of 32°, therefore 140° have been absorbed to melt the ice, and are not discoverable by the senses or by the thermometer.§

---

* Dr. Hare.

† Ice at 32°, is a radiant point of heat in an atmosphere of 0, and a freezing mixture, e. g. salt and snow producing a cold of 0, would be, relatively, a warm point in a medium of 40° below 0.

‡ The freezing and melting points of all bodies are the same for each particular body, but no two coincide, unless by chance; e. g. solid mercury melts at—39 solid water or ice at+32°. Most bodies, as the metals, melt without becoming previously soft, but others which are bad conductors, become soft first, as butter and sulphur.

§ Several other experiments of Dr. Black, go to prove the same result, namely that while ice is melting, a quantity of heat enters into it, without raising its temperature, which would raise that of water 140°.

(*d.*) *Freezing water gives out* 140° *of heat.*—This warms the incumbent air, which rises and affects a delicate thermometer, suspended above the freezing fluid. Freezing is therefore a warming process, and sensibly mitigates the severity of winter; the 140° being nearly the whole difference between the extreme climates of the globe, and being given out from the extensive surface of the freezing waters and plants, which are imbued with moisture, it greatly mitigates the atmospheric cold.

(*e.*) *Melting ice, especially if suspended, is attended by a descending current of cold air*, which is perceptible even to the hand, and still more, by means of a delicate thermometer. Liquefaction is therefore a cooling process, as is perceived also from the chilly air produced by melting snow in a bright day.

(*f.*) *Water cooled below* 32°, *if agitated, congeals into a spongy mass of ice; the evolved latent heat raises the temperature to* 32°, *and a part of the ice slowly melts again.*—Water may be cooled 20° or more below the freezing point, or 32° of Fahr. This is best done in a tall vessel, with a narrow mouth, and with a film of oil over the surface of the water; it happens often accidentally in domestic vessels, in cold weather. Water thus cooled, immediately commences freezing, if a particle of ice or even a crystal that is floating in the air, happens to enter the fluid.

(*g.*) *All solids absorb heat when becoming fluid and retain it while in that state.*—The quantity of heat is different in different cases, and is to be learned only by experiment.

Sulphur absorbs 143°.68 of Fahr. spermaceti 145°, lead 162°, beeswax 175°, zinc 493°, tin 500°, bismuth 550°.—*Black, Henry.*

(*h.*) *The particular quantity of heat which renders a substance fluid, is called its latent heat, or caloric of fluidity.*—The word latent was used by Dr. Black, merely to denote the condition in which the heat exists; *latet*, it lies concealed.

It is not a different kind of power, but merely heat in an insensible condition and manifesting its character by a peculiar effect, that of producing fluidity.

(*i.*) *Freezing mixtures, depend upon these principles.*—One ingredient in them, is always a solid, and in producing the effect of generating cold, this solid always melts or liquefies, and thus absorbs heat. When both substances are solid, as snow and muriate of lime, or snow and caustic potash, or snow and common salt, the effect is of course greater.

(*j.*) *Heat is evolved during the conversion of fluids into solids.*—This is well illustrated by the slacking of lime and the mixing of water with burned plaister of Paris, in both of which cases, the water becomes solid and heat is evolved.

A saturated solution of sulphate of potash precipitated by alcohol evolves considerable heat, when the salt congeals.—*Henry.*

(*k.*) *Were there no absorption of heat to become latent during the melting of ice, countries covered with snow might be instantaneously devastated.*—The torrents are even now, very destructive; then, they would be ruinous. Snow and ice would *instantly* melt, as soon as the temperature rose above 32°, but as the absorption of 140° of heat is indispensable, the process is necessarily a slow one.

(*l.*) *The heat absorbed in liquefaction, is given out again in freezing.*—Thus one cause tends to correct the effect of the other, and both causes conspire to regulate the temperature; for thawing is a cooling, and freezing is a warming process.

IV. VAPORIZATION AND GASIFICATION OR THE FORMATION OF AERIFORM BODIES.

Introductory Remarks.

Weight and pressure of the atmosphere.—This subject belongs to mechanical philosophy,* but it is impossible to make any progress in investigating the nature of aerial agents, without taking into view the pressure of the atmosphere. Its existence is fully demonstrated, by the rise of water in a pump, and by the stationary condition of the column of mercury in a barometer tube, as well as by many common occurrences.† The pressure, in any given place, varies at different times, but the medium is about fifteen pounds on the square inch, corresponding to a column of thirty inches in the barometer; to about thirty three feet of water, and to columns of other fluids varying in height according to their specific gravity.

Taking the doctrine of atmospheric pressure for granted, we proceed to aëriform bodies.

(*a*) *An aëriform body is one having the mechanical properties of air;*‡ *a vapor is a transient aëriform body, condensible by cold, or pressure, or both united; a gas is supposed to be permanently aëriform under every degree of pressure and cold.*—Some latitude is allowed in the use of these terms, and a few bodies continue to be called gases, which have been condensed; e. g. ammonia, euchlorine, sulphurous acid, sulphuretted hydrogen, carbonic acid, nitrous oxide, cyanogen, muriatic acid, and chlorine.[*]

---

* Consult Enfield's Philosophy, and any other treatise on Natural Philosophy.—This subject and that of statical pressure in general, is ably illustrated by Dr. Hare, in his Compendium, p. 25.

† It is now said that flies and other insects walk on the ceiling of a room with their backs downwards, in consequence of the peculiar webbed structure of their feet, which enables them to press the wall so closely, that little or no air intervenes, and thus the pressure of the atmosphere keeps them in their places.—L. U. K.

‡ Atmospheric air has, by pressure, been reduced to $\frac{1}{123}$ part of its volume, without losing its elastic form.

Strictly, the distinction between vapors and gases, although convenient in description, is unimportant. A vapor is derived from a body whose vaporific point is within our reach; but that of a true gas, is lower than our means will enable us to go.

(*b.*) *Caloric converts both*[†] *solids and fluids into gases, and vapors.*—Camphor, benzoic acid, and carbonate of ammonia, are easily converted into vapor, by being thrown upon a warm iron; a bell glass may be placed over them to catch the vapor. Some solids are volatilized without previous fusion—sal ammoniac and arsenic are of this number.

(C.) WITH EQUAL PRESSURE AND PURITY, EVERY LIQUID HAS A FIXED BOILING OR VAPORIFIC POINT; e. g. water, the barometer being at 30 inch. boils at 212°; ether, at 96° or 98°;[‡] alcohol, 173° to 176°.[§]

Water in a glass vessel boils at 214° or 216°—in a metallic vessel, at 212°. The boiling point in most liquids, is lowered several degrees by putting in chips of wood, coils of wire, metallic filings, pounded glass, &c.—The bubbles of steam are thus broken, and the heat escapes more rapidly. Dr. Bostock thus reduced the boiling point of ether, 50°, and that of alcohol, 30°.[||]

(*d.*) *The steam or vapor, is of the same temperature with the boiling liquid.*

(E.) PHENOMENA OF EBULLITION—explained by the instance of water. As the water is warming from the common temperature, it is first thrown into currents by the change of specific gravity, and when it arrives at 212°,[¶] elastic vapor then forms at the bottom of the fluid, and from its levity ascends, is condensed and disappears; it is followed by other bubbles, and when the water is thus all heated to the boiling point, the vapor passes through uncondensed, and is dissipated at the top. The water remains at 212° till the last drop is exhaled.

The old theories of palpable fire, or matter of caloric, of air bubbles passing through the water, and thus causing its agitation, &c. are untenable, and unworthy of discussion. Water, in the aëriform state, or steam, is the true cause of the mechanical movements in the boiling fluid, and the cloud which we see in the air near the surface is the vapor condensed into minute drops resembling a fog or mist. The singing arises from the escape of innumerable air bubbles, and the crackling noise, that precedes boiling, and ceases when it begins, is owing to the formation of elastic vapor, and its immediate condensation by the colder fluid above.

---

[*] See Mr. Faraday's experiments in Philos. Transac. part II. for 1822, and Am. Jour. Vol. 7 pa. 352.

[†] Dr. Black laid the foundation of the philosophy of vapors and gases, or in other words, of aëriform bodies, by his discoveries respecting latent heat, and by proving the distinct existence of an aëriform body, different from common air, namely, carbonic acid gas, called by him, *fixed air*. The period of this discovery was 1757.

[‡] Dr. Ure says 100°.

[§] For exceptions, See Henry, 10th Lond. Ed. Vol. I. pa. 114; Ann. Philos. new series, IX. 296. Ann. de Chim. et de Phys. tom, VII. pa. 307; and Jour. Science, Vol V. pa. 361.

[||] Ann. Phil. N. S. Vol. IX.

[¶] And also, when the vapor has acquired elastic power sufficient to lift both the atmosphere and the superincumbent fluid.

(*f.*) *Perfectly formed vapor is invisible.*—If water or other fluid be boiled in a glass flask, the space above the water, appears as if the vessel were empty, and the cloud at the mouth consisting of condensed steam, in the form of mist, would not be seen, if the air were of the temperature, 212°.

Ether, in thin glass vessels, is easily vaporized by applying boiling water, and condensed again by cold water.

(G.) *The latent heat of steam is about* 950° *or from that to* 1000°. —Dr. Ure adopts the latter number, which is probably correct. This is proved, by distilling one gallon of water, and condensing the vapor in a worm immersed in ten gallons of the same fluid, each of which will receive nearly 100° of heat, and this multiplied by 10, gives the above result very nearly.[*] Or one gallon of water in steam, will heat six gallons from 50° to 212°; $\overline{212-50}\times 6=972=$ latent heat of steam very nearly.

Hence, steam is an excellent vehicle of heat, and is very useful in cookery, in heating manufactories, drying gunpowder, and chemical precipitates, in heating baths, dye vats, and apartments for invalids; in making pharmaceutical extracts, and in many other cases. Large vessels of wood are employed with great economy because they can be heated by steam.

(H.) PRINCIPLE OF DISTILLATION.

Caloric, combining with the more volatile part of a fluid, raises it in vapor; it is again condensed by the cold water of the refrigeratory, which thus becomes rapidly hot, and must be often changed; this is usually done by a stream of cold water conveyed into the condenser; on one side, hot water runs out, and on another, cold water runs in.[†]

A retort and receiver is the simplest distilling apparatus; the fluid in the retort is made to boil, and the vapor is condensed in the receiver, which is kept cold for that purpose. *Sublimation is the same thing in principle, as distillation,* but the vapor is condensed in the solid form; this is seen, in the case of camphor, sulphur, benzoic acid, corrosive sublimate, calomel, arsenic, &c.

---

[*] Due allowance being made for the sensible heat, and for waste. Henry, 10th Lond. Ed. Vol. I. p. 127.

[†] Col. Wm. Moseley of New Haven, ingeniously avails himself of the cold water at the bottom and of the hot water at the top of the condensing tub, to supply baths conveniently and economically.

Distillation in vacuo, although it is attended by no economy of heat, is a good mode of conducting the process, where the product would be injured by a high temperature.

Vinegar as commonly distilled, has often an empyreumatic taste, but if distilled in vacuo, it requires only 130° of heat, aud the product is pellucid and fine.—L. U. K.

In these cases, the vacuum is obtained either by driving out the air by the vapor, and then closing the aperture of the receiving vessel, or, by applying a syringe or air pump to the receiver, cold being also of course in all cases applied to the receiver.*

(*i.*) *The specific heat of the vapors of different fluids is different,* and can be ascertained by experiment only.

Table of latent heat of vapors.†

	Ure's Dic. 17.	Despretz, Ann. de Chim. &c. xxiv. 329.	
Vapor of Water, at 212°	1000.		955.8
Alcohol, sp. gr. 0.825,	457.	(sp. gr. .793,)	373.86
Sul. ether, boiling point 104°,	312.9	(" " .715,)	163.44
Spt. turpentine, " about 310°,	183.8	(" " .872,)	138.24
Petroleum,	183.8		
Nitric acid, (sp. gr. 1.494—boiled at 165°,)			550.
Liquid ammonia, (sp. gr. 0.978,)			865.09
Vinegar, (sp. gr. 1.007,)			905.

The force of vapor at the boiling point is the same in all fluids; it is equal to 30 inches of mercury, and in all fluids, is the same for an equal number of degrees above and below ebullition, but fixed oils, sulphuric acid and mercury, afford no readily appreciable vapor under the boiling point.

---

* In consequence of a tax laid by the English parliament on the Scotch stills, by which they were to pay thirty shillings a year on every gallon of the capacity of their stills, it became their interest to make them work as fast as possible, and they made such improvements in the construction of their stills, that, although the tax was augmented by degrees from thirty shillings a year on a gallon, to fifty four pounds, they still continued to carry on the business with advantage. The improvements consisted chiefly in making the still very broad and very flat, so that only a small depth of wash could be in it at once, leaving a very large orifice for the escape of the vapor, having an internal moving apparatus for agitating the wash, to prevent its burning, and another in the upper part of the still to break the frothy effervescence, when it would be in danger of boiling over. The fire was applied to a very large surface; the ebullition was very rapid and general; no pressure was opposed to the escape of the vapor, and thus they arrived at such astonishing rapidity in the distillation, as to run off their stills of forty or fifty gallons capacity, three times in an hour, or seventy two times in twenty four hours, (see report on the Scotch Distillery, Phil. Mag. Vol. VI. pa. 76,) and by improvements still subsequent, they brought the process to such perfection, that a still of the capacity of forty gallons in the body, and three in the head, charged with sixteen gallons of wash, could be worked four hundred and eighty times in twenty four hours, viz. seven thousand six hundred and eighty gallons of wash could be distilled, and as the wash would afford eighteen per cent of spirit, it follows, that one thousand, three hundred and eighty two gallons could be distilled from a still of this capacity in twenty four hours, the still could be worked off therefore, twenty times in an hour, or once in three minutes, and gave about fifty eight gallons an hour, or near a gallon in a minute.

† Quoted from Henry, 10th London edit. Vol. I. p. 125.

(*j*.) *By being converted into steam, a cubic inch* of water becomes nearly a cubic foot* or 1728 cubic inches. Dr. Black and Mr. Watt estimated the enlargement at nearly 1800 times. According to Gay Lussac it is 1698 times. Alcohol, in vapor, under the common pressure, occupies 659 times the volume that it did when liquid, and ether 443 times. The specific gravity of steam is 623, air being 1000, but the vapor of alcohol is half as heavy again as air, and that of ether more than twice and a half as heavy, and generally with a few exceptions, the lower the boiling point of a fluid, the more dense is the vapor formed from it.

(K.) THE PRESSURE OF THE ATMOSPHERE, AND PRESSURE IN GENERAL, EXERTS AN IMPORTANT INFLUENCE ON VAPORIZATION.

As already observed, no correct conclusions respecting aëriform bodies can be formed, without taking this subject into view.

(*l*.) *The pressure of the atmosphere is measured by the column of mercury which it is capable of sustaining.*—A glass tube not less than 32 inches long nor over half an inch in diameter, closed at one end, being filled with mercury, and having its mouth first closed by the finger, and then inverted and opened under the surface of mercury, exhibits the amount of atmospheric pressure, vibrating on both sides of 29 or 30 inches, which is about the medium of different climates, seasons and countries.†

(*m*.) *At the medium pressure, pure water boils at* 212° ; *if the pressure be diminished, water and all fluids boil at a lower temperature.*—This is shewn by the air pump, and by the Torricellian vacuum.‡ Natural variations of atmospheric pressure vary the boiling point about 5°.

(*n*.) *According to Dr. Black, fluids boil in vacuo with* 124° *less of heat than under the pressure of the atmosphere;* others say with 145° less, if estimated in the Torricellian vacuum.§

As we ascend, it requires less heat to make water boil; on the top of Mount Blanc, it boils at 187°,‖ and on the range of Pasco, Peru, at 180°.¶ In the Rev. Mr. Wollaston's thermometer, each degree near the boiling point is divided into 1000 parts. Each degree of Fahr. is equivalent to 0.689 of an inch of the barometer, indicating an elevation of 530 feet. The 1000th part of a degree in Wollaston's thermometer is therefore equivalent to about six inches, and the height of a common table produces a manifest difference in the boiling point of water.[*]

---

* Weight 252 grains. The specific gravity of steam at 212° and of the force of 30 inches of mercury, in pressure, is to dry air as 10 to 16.—*Henry.*

† See Dr. Hare's experiments, in his Compendium.

‡ For a table, see Henry, Vol. I, p. 116, Lon. Ed. 10.

§ The space above the mercury in a barometer tube : it was called after its discoverer Evangelista Torricelli.

‖ The monks at one of the highest monasteries on the Alps, complain that they cannot make good *Bouillie*, (milk porridge,) because the water boils so soon —*Paris' Pharmacologia.* A digester would remove the difficulty.

¶ Am. Jour. Vol. XVII. p. 50.

This delicate instrument therefore answers the purpose of a barometer, it being necessary only to make water boil in order to determine the elevation of the place.

The boiling point of water is raised by having salt dissolved in it, and the steam has the temperature of the boiling fluid, and so in other cases.[†]

(o.) *Slight variations of pressure may be exhibited in glass vessels.*—Boil water in a flask until the air is all expelled by the steam; cork it while boiling; if tight, it will continue to boil, and the more rapidly, if it be cooled, as by touching it with or immersing it in cold water, and the boiling will be repressed or stopped by hot water.

In a retort corked in the same manner, the same phenomena are still more strikingly exhibited; the water, if shaken after all is cold, falls like lead, thus illustrating the principle of the water hammer.[‡]

Water, boiled in a flask, furnished with a stop cock, has its ebullition repressed by closing the key for a very short time; on opening it, it boils violently again, and so vice versa. This must be done with caution, the operator avoiding exposure both to the mouth and bottom of the vessel. All these effects depend on variations of pressure.

(P.) GREAT VARIATIONS OF PRESSURE ARE SAFELY EXHIBITED IN STRONG METALLIC VESSELS.

In Papin's digester, or any strong boiler, fitted with a cover, stopcocks and valve, the vapor of boiling water or other fluids may be confined; then the temperature of the fluid will rise as the pressure increases, and the ebullition will be repressed or stopped. Water may be heated in this manner to 400° of Fahr. or more; the danger of explosion is of course greater in proportion to the heat;[§] the machine being suddenly opened, a jet of steam rushes out with great violence, and the temperature of the water falls.

Mr. Southern's table of pressure and temperature is copied from Henry.[||]

---

[*] Henry, and Phil. Trans.

[†] Eng. Quar. Jour. Vol. XVIII.

[‡] This is owing to the want of atmospheric resistance, and shews that rain would fall like shot if it were not resisted by the air.

[§] As formerly believed, although now controverted by Mr. Perkins; see Jones' Journal, and American Jour. Vol. XIII, p. 52. Mr. Perkins thinks that the pressure of steam will not be in proportion to the temperature, unless there be an abundant supply of water to generate new steam and thus add to the quantity. Aside from this, the steam is no more expanded by increased heat, than air or any other elastic fluid would be.

[||] Vol. I, p. 122, Lond. Ed. 10.

Atmospheres.	Pressure in inches of mercury.	Temperature. Fahr.
1	29.8	212.0
2	59.6	250.3
4	179.2	293.4
8	238.4	343.6

(*q.*) *The latent heat of steam may be shewn by the digester.*—Five gallons of water are heated to 400°; the orifice being opened, one gallon flies away in the form of steam; the resulting temperature is 212°; therefore one gallon in steam has carried away heat represented by $5 \times 188 = 940 =$ nearly the latent heat of steam; for $400° - 212 = 188$, and there were five gallons of water.

(*r.*) *The latent heat of condensed steam, if suffered to pass into cold water, makes it boil quickly, and it soon melts ice.*—Great noise is produced by steam striking cold water; this is owing to its sudden condensation, and the noise grows less as the water becomes hotter, till finally the steam passes almost silently through water, at or near 212°, like a gas, and is not condensed.[*]

The better way to heat water, is to surround by steam, the vessel containing the water to be heated. Mr. Parkes heated twenty gallons in this manner, in six minutes, from 52° to 190°, in eight minutes to 200°, in ten minutes to 208°, and in eleven to 212°.—L. U. K.[†]

High steam does not scald, because it is cooled by its sudden expansion, and it blows along with it a mass of cold air; indeed it is no longer high steam, but common steam partly condensed. It also blows a burning brand powerfully, but if held too near, it extinguishes the fire in consequence of the condensation of the steam; it does not scald the hand, at a few inches from the orifice. The agent in the combustion is not so much the steam as the air which it blows along; still, at a very high temperature, the steam may be, and probably is decomposed, giving oxygen to the carbon, and hydrogen to the flame.

There is a popular impression that a boiling tea kettle does not burn the hand, but that, if it ceases boiling, it will produce that effect; perhaps there is a mistake in the fact; and this is the more probable, as the trial is of course made in a hurried and imperfect manner.

(*s.*) *The density of steam confined over water, is directly as its elasticity;* that is, the higher the temperature and the greater the elasticity, the greater is the quantity of water contained in steam of the same volume.[‡]

---

[*] It is said however that water heated in this way is still two or three degrees short of the boiling point.—L. U. K.

[†] Quoting Parkes' Chem. Essays.

[‡] Henry, Vol. I, p. 122, Lond. Ed. 10.

(T.) "*The same weight of steam contains, whatever may be its density, the same quantity of caloric; its latent heat being increased, in proportion as its sensible heat is diminished;* and the reverse."*—*Henry.*—Water distilled in vacuo at 70°, gave a vapor which, when condensed, indicated latent heat amounting to 1200° or 1300°. Hence there is no economy of heat in distilling in vacuo, for, as the sensible heat is diminished, the latent heat is increased.

(U.) *But steam formed at temperatures above* 212°, *suffers a diminution of latent heat by the increase of its sensible heat.*†—Hence there is no economy of fuel in the use of high steam, for more heat passes off by the chimney than where low steam is generated. There may be convenience and economy of room and money, in the arrangements of the machinery, and obviously the higher the temperature at which the steam is formed, the more of it there is in a given space, or the more water in the state of steam, and consequently the greater is the moving power.

(V.) *Fluids under vast pressure, may be converted into vapor with only a small augmentation of volume.*—This was done by M. de la Tour,‡ in glass tubes; alcohol of the sp. gr. .837, and occupying about $\frac{2}{5}$ of the capacity of the tube, became transparent vapor by expanding to a little over three times its first volume, and with a pressure of 119 atmospheres, or 785 lbs. on the square inch; the temperature was 404.6° Fahr.

Ether at 369° of Fahr. became vapor, under 38 or 39 atmospheres = 576 lbs. to the square inch, and the vapor occupied less room than that of alcohol or naptha.

Water, with a trace of carbonate soda, required a little over four volumes to become vapor. In these experiments, the presence or absence of atmospheric air made no difference, and on cooling the tubes, the fluids reappeared, the vapor being condensed.

At these high temperatures, water can decompose glass, by separating its alkali, and thus causing the glass to become cloudy.

---

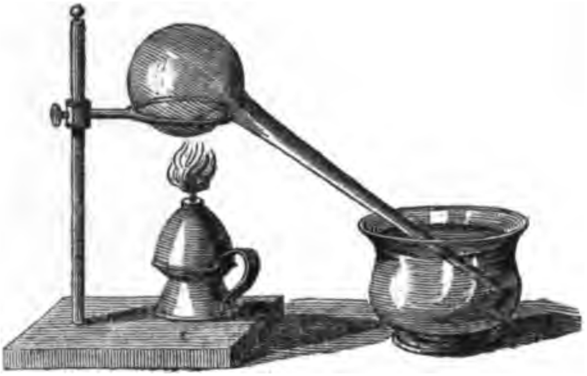
* That is, e converso, as the sensible heat increases, the latent heat diminishes, so that equal weights of steam *incumbent over water*, at whatever temperature, contain the same quantity of heat; or the total heat of steam is a constant quantity. A given quantity of vapor of the same substance, whatever may be its temperature, and elasticity imparts to cold water the same quantity of heat.

† Manchester Memoirs, Vol. II, new series. Brewster's Edit. of Prof. Robinson's works.

‡ Annales de Chimie and de Physique, XXI. 127—178. XXII. 400. Annals of Philos. V. 290.

(W.) OF THE STEAM ENGINE.—*Dr. Hare.*

The principle of Savary's Steam Engine illustrated.



"A matrass, situated as in the above figure, and containing a small quantity of water, being subjected to the flame of a lamp, the water will soon, by boiling, fill the matrass with steam. When this is accomplished, bubbles of air will cease to escape from the neck of the matrass, through the water in the vase."

"The apparatus being thus prepared, on removing the lamp, the water of the vase will quickly rush into the vacuity, in the matrass, arising from the condensation of the steam."

*Of Savary's Engine.**

"The celebrated engine of Savary, which led to the invention of that of Newcomen, and finally to the almost perfect machine of Bolton and Watt, consisted essentially of a chamber in which steam, after being introduced from a boiler, was condensed by a jet of cold water, as in the experiment above described."

"Just before the condensation of the steam, the communication with the boiler was cut off, and a cock or valve, was opened in a pipe descending into a reservoir of cold water. The chamber was consequently filled with water, which was expelled through an aperture opened for the purpose, by allowing the steam to enter again above the water. The aperture through which the water escaped, and that through which the steam entered, being closed simultaneously, the operation of condensing the steam and filling the chamber with water was reiterated, as likewise in due succession the other steps of the process, as above stated."

---

* The Marquis of Worcester in 1663 published in his book (whimsically entitled,) The Century of Inventions, an obscure hint of the contrivance, which Savary carried into effect in 1669.

Of Newcomen's Engine.

"The great objection to Savary's engine, was the waste of steam arising from its entrance, over the water, into a cold moist chamber. So great is the power of cold water in condensing steam, that had the steam been introduced, below the water, it could not have been expelled until ebullition should have been excited; but heat, being propagated downwards in liquids with extreme difficulty, the steam entering from above was not condensed so rapidly as to paralyze the engine."

"To diminish the very great loss sustained in the engine of Savary, Newcomen, instead of causing the vacuum produced by the condensation to act directly upon water, contrived that it should act upon a piston, moving, air tight, in a large cylinder, like a pump chamber. The piston was attached to a large lever, to the end of which, on the other side of the fulcrum, a pump rod and a weight were fastened. By the vacuum arising from the condensation, the piston, being exposed to the unbalanced pressure of the atmosphere, was forced down to the bottom of the cylinder, drawing up, of course, the rod and weight at the other end of the lever."

"The cylinder being replenished with steam, the weight on the beam drew up the piston in the cylinder, and pushed down the pump rod, and thus by the alternate admission and condensation of steam, the piston and pump rod were made to undergo an alternate motion, by which the pump, actuated by the rod, was kept in operation.—Although less caloric was wasted by Newcomen's engine than by Savary's, there was still great waste, as the cylinder was to be heated up to the boiling point each time that steam was admitted, and to be cooled much below that point as often as condensation was effected."

*In Watt and Bolton's Engine,** steam from the boiler lifts the piston, and steam let in above, depresses it; condensation of the steam taking place at the same time, by communication with a cold vacuum, connected with an air pump; thus the stroke and condensation are alternate, the cylinder is kept constantly hot, and the condenser cold, by water pumped in by the working machinery, from below; the hot water, formed from the condensed steam, is returned to the boiler, by the operation of the machinery; the atmosphere does not operate, except on the horizontal section of the rod of the piston. In this machine, the steam is constantly working, while in Newcomen's it was inert half the time, and not only was the cylinder below the piston, chilled at every stroke, by the cold water, but above the piston, by the cold air. Mr. Watt's great improvement consisted in shutting out the atmosphere entirely, and in causing the condensation of the steam, at a distance from the cylinder, which is in that way maintained at the boiling point. Thus both the upward and downward movement of the piston, is caused by the elastic effort of the steam.

---

* This engine, the most splendid present ever made by science to the arts, is, in common with other steam engines, far from using the whole power that is generated; for Clement and Desormes conclude, from their own experiments that the best steam engines have brought to bear not more than one twelfth part of the power of steam, as calculated by theory.—*Then.* I. 85, *5th Edit.*

Wolf's, Evans's or the high Pressure Engine.—There is no condensation of the steam, which is driven out alternately, above and below the piston, against the atmosphere. As these engines work simply by dead lift of expansive steam, great strength is necessary in the machinery. The principal advantage is in economy of machinery, and room; not of fuel. On account of the strength and smaller size of the boilers, explosions are less frequent, than in the low pressure engines, but they are more destructive. *Dr. Hare* remarks, that "the engines in our steam boats, generally combine the two principles—using steam that will support a weight, of from seven to fifteen pounds, per square inch, and that a true Bolton and Watt steam engine, having an ample supply of water, cannot explode while the safety valve is of a proper size, and not improperly loaded."*

Perkin's Generator.†—The pressure is far beyond any thing heretofore used; eight hundred pounds, and even one thousand pounds, on the square inch, is not an uncommon pressure and fifteen hundred has been frequently used. The generator is very small; it is heated in a furnace; there is no boiler, but water is injected by the machinery, as it is wanted, about one gallon at a time. At Woolwich of late,‡ the steam was so heated, as to set fire to wood, tow, &c. and to ignite the iron generator, at the orifice made for the emission of the steam. Mr. Perkins says, that 4000 atmospheres = 65,000 lbs. on the square inch, is the maximum pressure of steam.§

(*x*.) *Mr. Perkins states that his high steam will not issue from an orifice, in his generator, one fourth of an inch in diameter,* the pressure being 800lbs. on the square inch, but when cooled down to the common working temperature, it issues with a roaring noise, so as to be heard half a mile, and powerfully blows a burning brand which it would not do before.*

---

* If these conditions were observed, all steam engines would be much safer than they are; but in the high pressure engines, the metal is necessarily exposed both to the weakening effect of heat, and to the mechanical strain arising from vast pressure; while in the low pressure engines, these causes are comparatively feeble in their operation. The rule for loading the valve in Mr. Watt's original engines, was two and a half pounds for each square inch.

† See Am. Jour. especially Vol. XIII.

‡ Jones' Journal, Nov. 1827.

§ The elastic energy of common steam is derived from the latent heat × sp. gr. + the temperature or thermometric tension.—*Ure.*

(y.) *Cause of the explosion of steam boilers.*—According to Mr. Perkins and Mr. Hazard, of Philadelphia, it is caused mainly by the fact that the boiler, by want of water, becomes heated unduly, and heats the steam excessively; the water then dashing up in jets, caused by the ebullition, or even by the spontaneous or intentional lifting of the valve, is converted into steam, *in such great quantities*, that it cannot be retained, and therefore bursts the boiler. A boiler full of steam, without access to water, it is said, may be heated even to redness, without explosion, steam being no more expansible than an equal volume of air, but if there be water present to form more steam, then the pressure becomes uncontrolable. Red hot iron boilers, by decomposing water, doubtless generate hydrogen gas, when the water is suddenly let in, and this, being incapable of condensation, of course, greatly increases the tendency to explosion, which the boiler, thus rapidly oxidized, is unable to resist.

STEAM ARTILLERY.

Mr. Perkins, by applying steam to the propulsion of cannon balls, is able to throw sixty, four-pound balls, in a minute, "with the correctness of a rifled musket, and to a proportionate distance."

A musket may be made to throw, by means of steam, from one hundred to one thousand balls in a minute, and it is not doubted that a constant stream of balls may be discharged during a whole day, if required. From five hundred to one thousand bullets have actually been thrown per minute, the steam, all the while blowing off at the escape valve.† It is said, however, that the range of shot, propelled by steam, is much more limited than if fired in the usual way.

Principle of Cupping.

A cup partially exhausted of air, by burning paper in it,‡ and suddenly applied to the soft parts of the body, allows the flesh to be forced into it, by atmospheric pressure, and after scarification, the renewal of the process, causes the blood to ooze out. The emission of blood, at great heights, as experienced by Humboldt and his companions on the Andes, was probably owing to the prevailing force of vascular action, under a greatly diminished pressure, on the surface of the body.

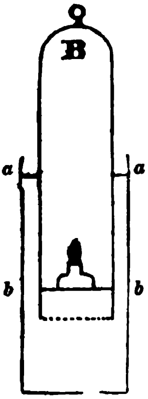
---

* Mr. Perkins supposes that heat is matter and that its accumulation at the orifice imprisons the steam.

† Am. Jour. Vol. XIII pp. 44, 45.

‡ Exhausting syringes are said to be now occasionally used.

ADDITIONAL EXPERIMENTAL ILLUSTRATIONS OF THE NATURE OF AERIFORM BODIES.



1. *Aëriform bodies can displace gross fluids or prevent their entrance into cavities which they occupy.*—The figure represents a cylindrical glass containing a colored fluid, upon which is a taper floating upon a wide, flat and thin cork; a narrow and tall bell glass is placed carefully over the light, and depressed as far as it can be, without making the fluid overflow; the light is then seen at *b b* which is the surface of the fluid, within the jar, while *a a*, shows its position on the outside. It is hardly necessary to mention that this is the principle of the diving bell.

2. *The candle bomb* is a spherule of glass containing a little alcohol, ether or water; it has a stem, which is stuck into a candle, so that the ball shall be in, or just above the wick, which is touched with oil of turpentine, that it may be lighted promptly; when this is done, the fluid is vaporized, and the glass soon explodes; it should be placed behind a screen.

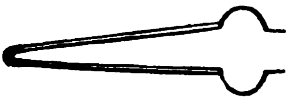
3. *A glass flask containing water over an Argand or spirit lamp*, or over a few burning coals, shews the phenomena of boiling.

4. *The Eolipile.*—A copper ball with a recurved tube, shews the force of steam, issuing from a capillary orifice; it will vigorously blow a burning brand, or the entire fire, if placed on the hearth. If ether, or alcohol, or oil of turpentine be substituted for the water, the jet of vapor is then inflammable. The fluid is introduced as it is into the thermometer ball.

5. *Ether is easily vaporized.*

(*a.*) In a flaccid bladder, furnished with a stop cock and tube, let a little ether be heated by contact with hot water; it will soon inflate the bladder, which being compressed, will give a jet of inflammable vapor; or cold water applied to the bladder will condense it.

(*b.*) A tall thin glass jar, filled with water, and standing in the pneumatic cistern, has a little ether introduced, by turning up beneath it, a vial filled with that fluid: the jar should be secured by recurved tongs, of this form, or by a ring on a stand: boiling hot water, from a tea kettle, being poured on the top of the jar, the ether boils, and drives the water out; if the jar be quickly lifted out of the water, the etherial vapor may be inflamed by a candle, or if allowed to stand, the water will condense the vapor and will again fill the jar, except a small space occupied by extracted air.



(*c.*) Such a flask, as that represented at No. 11, p. 100, is filled with water, except an inch or two of the neck, which is occupied by ether; its mouth being covered by the thumb, it is inverted and secured in the pneumatic cistern, and treated as in (*b.*) and with the same result, only the return of the water especially if the neck of the flask is plunged deep, so that the water which comes in is very cold, may be sudden; it produces a violent whirl of the injected water, which, if it does not break the flask, makes a very pleasing experiment; if, when the etherial vapor fills the vessel, the thumb be used as a stopper, the ball of the flask may then be cooled, and the water let in gradually, without endangering the vessel, but the effect is much less striking.

(*d.*) *Ether boils instantly at the common temperature, in the Torricellian vacuum.*—Form this vacuum by using a strong tube, thirty-three or thirty-four inches long, and a half or three quarters of an inch in the bore, and then introduce a little ether through the mercury, in which the tube stands, by depressing a small essence vial full of that fluid, beneath the mouth of the tube, and turning it up; as soon as the ether arrives near the top of the tube, *it flashes into vapor*, with violent ebullition and drives the mercury half or two thirds down the tube; if the tube be then inclined in a position as nearly horizontal as possible, without removing its mouth from the mercury, a great part of the ether will be recondensed, and the vapor will be formed anew on raising the tube.

The above experiment is very strikingly exhibited by filling the tube with mercury, except an inch at the top, which is filled with ether, and then the orifice being closed with the thumb or the hand, it is introduced, in an inverted position, into the mercurial cistern, when as soon as the hand is withdrawn, the tube, at that moment occupied by the mercury and ether, becomes instantly, in a great measure filled with etherial vapor, which, as before, drives the mercury down.

6. A glass tube, six or eight feet long, and one inch wide, closed at one end, and the other fitted with a stop-cock, being screwed to the plate of the air pump, may be exhausted to the greatest degree that the pump is capable of; if the pump is a good one, the atmosphere, when the tube is unscrewed and opened beneath water, will force it up in a jet and nearly fill it: a colored fluid gives the most beautiful experiment.

7. If the exhausted tube be opened under mercury, a jet of that fluid will be thrown in, and the column that is formed may be thirty inches high. On lifting the tube out of the mercurial cistern, the atmosphere will enter, and, because there is still a good vacuum above the mercury, the latter fluid will be pushed up nearly or quite, to the top of the tube, and will then fall, and the same effect will

be exhibited several times, but each time in a diminishing degree, until it ceases.

8. CULINARY PARADOX.

*Ebullition by Cold.**—*Dr. Hare,* 8 *to* 14.

"A matrass, half full of water, being heated until all the contained air is expelled by steam; the orifice is closed so as to be perfectly air tight. The matrass is then supported upon its neck, in an inverted position, by means of a circular block of wood. A partial condensation of the steam soon follows, from the refrigeration of that portion of the glass which is not in contact with the water. The pressure of the steam upon the liquid of course becomes less, and its boiling point is necessarily lowered. Hence it begins again to present all the phenomena of ebullition; and will continue boiling, sometimes for nearly an hour."

"By the application of ice, or of a sponge soaked in cold water, the ebullition is accelerated; because the aqueous vapor, which opposes it, is in that case more rapidly condensed: but as the caloric is at the same time more rapidly abstracted from the water, by the increased evolution of vapor, to replace that which is condensed, the boiling will cease the sooner."

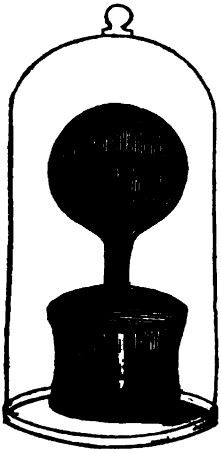
---

* This fact is pleasingly exhibited, by providing two cylindrical glass vessels, of one quart or two in capacity, (the quart or three-pint tumblers, sold in the shops, answer very well); into one of them pour cold, and into the other hot water; then immerse alternately in each, a flask which contains water that was, just before, while boiling, cut off, by a good cork, from the atmosphere; in the cold water it will boil vehemently, and in the hot it will cease boiling.

A retort if treated in a similar manner, is a still better instrument, because it presents in the ball, a large surface for warming or cooling; and a little cold or hot water poured on cautiously, while the retort is hanging in a ring, produces a very striking effect. If the retort be very thin, and especially if large, there is danger of its being crushed by the pressure of the atmosphere. I have repeatedly met with this accident, with both retorts and flasks; but it is not dangerous, as the fragments do not fly about.

9. AERIFORM STATE DEPENDENT ON PRESSURE.

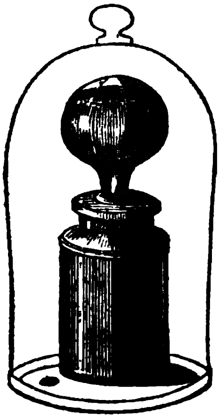
FIG. 1.



Proof that some Liquids would always be aëriform, were it not for the Pressure of the Atmosphere.

" A glass flask, fig. 1, being nearly filled with water, and having the remaining space occupied by sulphuric ether, is inverted in a glass jar, covered at bottom by a small quantity of water, to prevent the air from entering the neck of the flask. The whole being placed upon the air pump plate, under a receiver, and the air exhausted, the ether assumes the aëriform state, and displaces the water from the flask. Allowing the atmospheric air to reenter the receiver, the ethereal vapor is condensed into its previous form, and the water reoccupies its previous situation in the flask."

FIG. 2.



" The return of the ether, to the fluid state, is more striking, when mercury is employed, as in fig. 2 ; though, in that case, on account of the great weight of this metallic liquid, the phenomenon cannot be exhibited on so large a scale, without endangering the vessels, and risking the loss of the mercury."*

---

* It is pleasing to see so dense a fluid as mercury, especially as it is also brilliant and opake, becoming a truly transparent, invisible, and elastic vapor, and then by a slight depression of temperature, returning again to the fluid state. The boiling of the mercury in the thermometer ball and tube, during the construction of that instrument, exhibits this fact in perfection.

10. *Atmospheric pressure opposes and limits chemical action, where elastic fluids are to be generated or evolved.*

"Water would boil at a lower temperature than 212°, if the atmospheric pressure were lessened; for when it has ceased to boil in the open air, it will begin to boil again in an exhausted receiver; and those who ascend mountains find, that for every five hundred and thirty feet of elevation, the boiling point is lowered one degree of Fahrenheit's thermometer."

The boiling point is lowered by a diminution of atmospheric pressure.

"Water heated to ebullition in a glass vessel, having ceased to boil in consequence of its removal from the fire, will boil again under a receiver, as soon as the air is withdrawn."

11. *Boiling point raised by pressure.*

As the Boiling Point is lowered by diminution of Pressure, so it is raised if the Pressure be increased.

"Into a small glass matrass, with a bulb, of about an inch and a half in diameter, and a neck of about a quarter of an inch in bore, introduce nearly half as much ether as would fill it. Closing the orifice with the thumb, hold the bulb over the flame of a spirit lamp, until the effort of the generated vapor to escape, becomes difficult to resist. Removing the matrass, to a distance from the lamp, lift the thumb from the orifice: the ether, previously quiescent, will rise up into a foam, produced by the rapid extrication of its vapor."

"This experiment may be performed more securely, by employing a vessel of hot water, instead of a flame, to warm the matrass."

12. *Column of Mercury raised by vaporized Ether.*

An increase of Pressure results from constrained Ebullition.

"Having supplied a small flask with a little mercury, and a minute portion of sulphuric ether: through the neck, let there be a glass tube, so introduced, and firmly luted, as that it may be concentric with the vertical axis of the vessel, and extend downwards until nearly in contact with the bottom. If the flask thus prepared, be held cautiously over a spirit lamp, the ether will be more or less converted into vapor. The vapor being unable to escape, will soon cause the mercury to rise to the top of the tube. On the removal of the lamp, the mercury gradually falls to its previous situation."

It is better, as Dr. Hare has before recommended, to plunge the flask cautiously into hot water (of about 150°, or 180°,) as the pressure sometimes blows out the bottom of the flask, when, if over fire, a dangerous combustion would ensue.

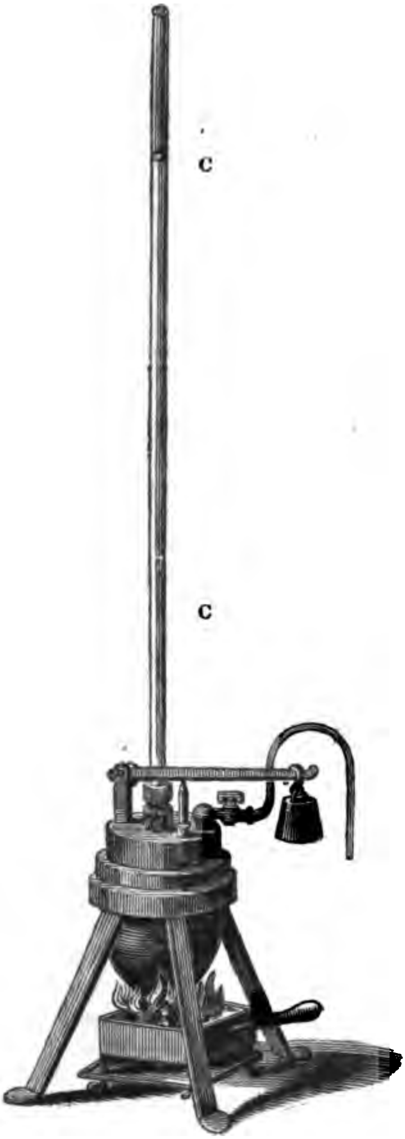
13. HIGH PRESSURE BOILER.

That the temperature of Steam is directly as the pressure, may be demonstrated by a small Boiler, such as is represented in the following cut.

"The glass tube in the axis, passes below the water in the boiler, and enters a small quantity of mercury at the bottom. The juncture of the tube, where it enters the boiler, is made perfectly tight. On the opposite side of the boiler, a tube, not visible in the drawing, descends into it. This tube consists of about two inches of a musket barrel, and is closed at bottom. The object of it is to contain some mercury, into which the bulb of a thermometer may be inserted, for ascertaining the temperature."

"When the fire has been applied during a sufficient time, the mercury will rise in the glass tube, so as to be visible, above the boiler; and continuing to rise, during the application of the fire, it will be found that with every sensible increment in its height, there will be a corresponding rise of the mercury in the thermometer. In front of the tube, as represented in the figure, there may be observed a safety valve, with a lever and weight, for regulating the pressure."

"It has been found, that when the effort made by the steam to escape, in opposition to the valve thus loaded, is equal to about fifteen pounds for every square inch, in the area of the aperture, the height of the column of mercury, C, C, raised by the same pressure, is about equal to that of the column of this metal, usually supported by atmospheric pressure, in the tube of a barometer."

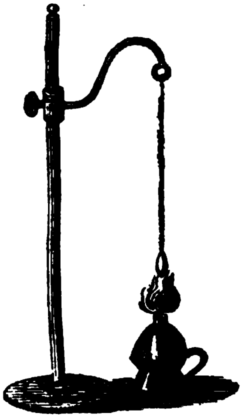


"Hence the boiler, in this predicament, is conceived to sustain an unbalanced pressure equivalent to one atmosphere, and for every additional fifteen pounds per square inch, required upon the safety valve to restrain the steam, the pressure of an atmosphere is alleged to be added. To give to steam at 212°, or the boiling point, such an augmentation of power, a rise of 38° is sufficient, making the temperature equal to 250°. To produce a pressure of four atmospheres, about 293° would be necessary. Eight atmospheres would require nearly 343°."

"When, by means of the cock, an escape of steam is allowed, a corresponding decline of the temperature and pressure ensues."

"If the steam, as it issues from the pipe, be received under a portion of water of known temperature and weight, the consequent accession of heat will appear surprizingly great, when contrasted with the accession of weight, derived from the same source.—It has in fact been ascertained, that one measure of water converted into aqueous vapor, will, by its condensation, raise about nine measures of water in the liquid form, one hundred degrees."

14. Explosive power of steam.



"If a small glass bulb, hermetically sealed, while containing a small quantity of water, be suspended by a wire over a lamp flame, an explosion soon follows, with a violence and noise which is surprising, when contrasted with the quantity of water, by which it is occasioned.

"In order to understand this, suppose that the bulb were, in the first instance, merely filled with steam, without any water in the liquid form. In that case the effort of the steam to enlarge itself, would be nearly in direct arithmetical proportion to the temperature; but when water is present in the liquid form, while the expansive power of the steam, previously in existence, is thus increased, more steam is generated, with a like increased power of expansion. It follows, that the increments of heat being in arithmetical proportion, the explosive power of the confined vapor will increase geometrically, being actually doubled, as often as the temperature is augmented, somewhat less than forty degrees of Fahr."

*Miscellaneous uses of steam.**

1. *For warming apartments*, especially large manufactories.—There is no danger from fire; the boiler may be even in another room, and as the steam is transmitted in tubes, it is thus condensed and gives out its heat.

"Every cubic foot in the boiler is equal to heating two thousand feet of space to an average temperature of 70° or 80°," and each square foot of surface of steam pipe will warm two hundred cubic feet of space.

2. *For drying muslins and calicoes and other goods.*—Either the stuffs are hung up in rooms and dried by steam pipes giving a heat of 100° or 130°, or they are made to pass around cylinders filled with steam. Delicate colors, such as scarlet and crimson, formerly faded by stove drying, are thus preserved from injury, although heated to 165°, and the people are healthy, which was said not to have been the fact when the rooms were warmed by stoves.

---

* Concisely mentioned before.

3. *Gunpowder is safely dried*, in a similar manner.

4. *By surrounding the vessels with steam, pharmaceutical extracts are made*, without injury to delicate principles. Chemical precipitates are sometimes dried in the same mode.

5. *Steam is employed in bleaching.*—Instead of boiling the stuffs with solution of potash, they are steeped in that alkali, and then hung up while wet, in a chamber which is afterwards filled with steam, which enables the alkali to dissolve and remove the coloring matter more effectually and more rapidly than in the old way.*

6. *It is applied to cookery.*—It is neat and effectual, and the same water may in fact be used twice; once in the boiler as water, and once, as steam, in another vessel, which may be made of tinned iron, and placed in any convenient situation, with which a communication should be established by a bright tin tube; the boiler must be furnished with a lid and a safety valve.

7. *It is used for heating baths and dye vats.*—The steam may be made to pass either through tubes, immersed in the water, or, it may be thrown directly into the water, which it will heat very rapidly. There should be a valve in the tube of communication to prevent the reflux of the water into the boiler.

Very large quantities of water may be thus heated in vessels of wood, and in one third part of the usual time.

8. *For creating a vacuum.*—This is perhaps more easily done by the action of steam than in any other way. The first effect when the steam engine is put into operation, is to expel the air, and large vessels may, in this manner, be almost instantly filled with steam, which, being quickly condensed, leaves a pretty good vacuum, containing little else than a feeble vapor of water.

An ingenious still has been constructed by Mr. Barry, for making vegetable extracts in vacuo; both still and receiver are freed from air, and as water will then boil at a temperature below 100°, the vegetable extracts are obtained stronger and without empyreuma or decomposition.†

(V.) NATURAL OR SPONTANEOUS EVAPORATION.

(*a.*) *This is the gradual wasting of fluids and of some solids at atmospheric temperatures.*—It takes place at the surface, and therefore is not attended with ebullition; it differs not at all in principle from vaporization; it is only more gentle and never produces any agitation.

(*b.*) *Not only all waters, but all animals and vegetables and men, and the entire surface of the earth give out moisture by evaporation.*—Place almost any thing, even ice itself, under an inverted glass which is kept cold, and vapor will be condensed in dew or frost if the cold be considerable. Camphor, carbonate of ammonia, and other volatile solids give off vapor so rapidly, that when placed in equilibrio in balances, they are soon found to lose weight.

---

* Murray's Elements, 6th Edit. Vol. I, p. 287. † Ibid, p. 143.

(C.) *The cause of natural evaporation is caloric. It produces from water, at every temperature, an elastic invisible vapor, whose elasticity increases with the temperature, and which sustains a corresponding column of mercury.*—Dalton and Gay Lussac have fully established this position. The theory, formerly so prevalent, that evaporation depends on the solution of water in air, is no longer tenable as the sole and sufficient cause, but it is still very possible,[*] that vapor may be dissolved in air. The lower the boiling point of a fluid, the more readily it evaporates.

(*d.*) *It has already been stated, (p. 87,) that the force of vapor is the same at the boiling point for every fluid;—it equals thirty inches of mercury, and is the same, in all cases, for an equal number of degrees above and below ebullition.*[†]—This is a curious fact; perhaps it would have hardly appeared probable, for instance, that the vapor of ether at its boiling point, 98°, of water at 212°, and of mercury itself at 656°, should each exert a power capable of sustaining in a tube, a column of that metal thirty inches in altitude.

EFFECTS OF NATURAL EVAPORATION.

(*e.*) *Evaporation produces cold because heat must be absorbed to form vapor.*—The evaporation of ether under the receiver of the air pump freezes water in contact with it, or having only a thin vessel between; so a stream of ether falling upon a thin glass tube, freezes water contained in it.

The sensation of cold in coming out of a bath, especially if warm, is owing to the absorption of heat to form vapor. The formation of vapor is a cooling process; it goes on extensively, and thus regulates natural temperature. In the hottest climates, evaporation from extensive surfaces of water, mitigates the heat, but where there is little or no water, as in the great African desert, the heat becomes intolerable.

Excessive degrees of heat have been occasionally endured by human beings in consequence of evaporation from their own surfaces.

"Sir Joseph Banks and Sir Charles Blagden, breathed for some time an atmosphere in a room prepared by Dr. Fordyce, which was 50° higher than that of boiling water," viz. at 262° Fahr. "The temperature of their bodies was not at all raised, though their watch chains and every thing else metallic about their persons were so heated, that they could not bear to touch them.[*] The thermometers which hung in the rooms always sunk several degrees when either of the experimentalists touched them, or breathed upon them. Some eggs and a beefsteak were placed on a tin frame; the eggs were roasted hard in twenty minutes, and the beefsteak was overdone in thirty three minutes. Water placed in the same room did not however acquire a boiling heat until a small quantity of oil was dropped on it, when it soon began to boil briskly. The evaporation from the surface of the water had prevented it from acquiring the heat of 212°; but when that surface became covered with a film of oil, the evapora- could not go on, and ebullition commenced."[†]

---

[*] Nor is it impossible or even highly improbable, that water may be, to a certain extent soluble in air, as there is obviously an affinity between the atmospheric gases and water; but the fact, if admitted, will not account for all the phenomena, without admitting the formation of vapor at all temperatures. It is even said that vapor formed at atmospheric temperatures, has the same amount of heat as that formed at the boiling point; the latent heat increasing as the sensible heat is diminished.

[†] See Dalton's tables.

"The oven girls in Germany often sustain a heat of from 250 to 280°, and one of these girls once breathed for five minutes, in air heated to 325° of Fahr. When the air of such rooms is damp, or the skin is rubbed over with varnish, the heat cannot be borne an instant."[‡]

In the case of Sir Joseph Banks and Sir Charles Blagden, it is stated that there was no remarkable evaporation from the skin; the insensible perspiration was doubtless greatly increased, and in such cases an immense perspiration usually happens, and it is this chiefly which either in a sensible or insensible form, renders such trials safe. A well varnished man would probably soon die in such circumstances, and probably could not live long at the common temperature.[§]

The cooling of liquors in hot countries, is effected by evaporation from skins containing water, from porous jars, &c.

Mr. Leslie, with the aid of sulphuric acid to absorb the vapor, froze water by its own evaporation under the exhausted receiver; sometimes he employed merely porous solids, as clay, or parched oat meal or flour, porous and burnt *whin stone*,[||] and porous, and ignited pieces of muriate of lime.[¶]

If the water has been previously boiled, the ice formed is firmer, although the process is slower. An earthen ware vessel is preferred for holding the water. A hemispherical earthen vessel, containing three pints of water, was placed by Mr. Leslie over a body of parched oat meal, one foot in diameter, and one inch deep, and the whole of the water was frozen by working the pump.

---

[*] "The heat of metals at 120°, is scarcely supportable; water scalds at 150°, but air may be heated to 240°, without being painful to our organs of sensation."—*Davy*.

[†] Phil. Trans. Vol. LXXVI, p. 271, Ann. 1775.—Quoted by Mr. Parkes.—Essays, 2d Lond. Edit. Vol. I, p. 70.

[‡] Parkes, quoting Hist. Acad. Sciences, 1764.

[§] Communicated.—Since reading "Wells on Dew," I have doubted whether the power of the animal system to endure such a high temperature were owing entirely to the cooling effects of evaporation. Physiologists maintain that this power of the animal system to endure a high heat, is connected with the vital principle.—*V. Sir Everard Home, in Phil. Tran.*

[||] The Scotch colloquial name for greenstone and other trap rocks.

[¶] The Pacha of Egypt procured a fine air pump for the manufacture of ice by Mr. Leslie's process.

By the skilful management of evaporation and radiation, ice is obtained at Benares, in a climate where, in the summer, the thermometer is never under 100°, and is often 110°.

Shallow pits or beds are made four or five feet wide, and about four inches deep, separated from one another by narrow borders, and so numerous as to cover an extent of about four acres. These pits are filled with dry straw in the middle of their winter, when the thermometer is about 40° of Fahr. On the straw are placed rows of shallow earthen pans containing a few inches of water introduced at evening. In the morning they find a little ice, which at sun rise is wrapped in flannel and carried to the ice house. Near Calcutta, a similar process is adopted. In the plains, excavations are made about thirty feet square and two feet deep, and covered about a foot deep with dried stalks of Indian corn or sugar cane. Unglazed earthern pans about 1¼ inch deep, are filled with soft water which has been boiled, and in the three winter months, some of it is frozen, every night, when the weather is clear. At sun rising it is carried, wrapped in flannel, to the ice house, which is a deep pit, lined with straw and coarse blankets, and covered by a thatched roof—the mouth is closed with straw.—L. U. K.

Quicksilver may be frozen by the united influence of evaporation, rarefaction and absorption.—If a pear shaped mass of ice containing the metal, be suspended over a large surface of sulphuric acid, and a good exhaustion obtained, it will freeze the quicksilver, which may be kept solid for several hours.—L. U. K.

The freezing of wet clothes exposed to the air when the thermometer is not so low as 32°, is occasioned by evaporation.

Plants are often injured by the frost when the thermometer is above freezing; this is the joint effect of evaporation and radiation.

Wine coolers are usually made of porous earthern jars unglazed; they cool the wine by evaporation from the surface; several of them on a table have an effect on the air around, which is perceptible to the guests. Rooms are cooled by sprinkling water around them, in hot weather.

In India, drapery is suspended around their dining halls, which are roofed, but open at the sides, and water being dashed on the curtains, the evaporation generates cold.

(*f.*) *Evaporation contributes to health, by imparting moisture to the atmosphere.*—The driest air contains moisture, which is often condensed upon cold objects, especially if they are good conductors.

maining constant, the tension of the confined vapor, will still continue unchanged; because a quantity of it will be condensed, proportional to the diminution of space, so that in fact, the remaining space contains the very same quantity of vapor as it did originally. The same law holds good, whether the vapor is pure or mixed with any other gas."[*]

(*j*.) *Mode of estimating the force of vapor.*—This has been already explained under the head of vaporization. Water is introduced into the Torricellian vacuum, and the depression of the mercury measures the force of the vapor. Vapor being produced at every temperature, even below freezing, a table was constructed by Mr. Dalton to express the force through a wide range of temperature.—This table, and the results since obtained by Dr. Ure,[†] may be inserted at the end of the volume. At the same distance from the boiling point, the force of vapor is the same in all fluids.

(*k*.) *Effect of vapor upon gases.*—It enlarges their volume, and that directly, in proportion to the temperature.[‡]

Gases are freed from their hygrometric moisture either by intense cold, or what is more usual, by exposing them to substances, which powerfully attract moisture; muriate of lime, which has been ignited, is the substance which is almost always used, and it is very effectual.

(*l*.) *Hygrometers.*—These depend, generally, upon a change of dimensions, in consequence of absorbing or giving out moisture.—A human hair becomes elongated by imbibing moisture, and returns to its former dimensions, when the moisture is withdrawn; this change is measured by an instrument, usually furnished with an index, and a graduated arc. Wood, cord, membrane, whalebone, &c. are similarly affected.

Cords are shortened in wet weather; this appears to be owing to the enlargement of their diameter, at the expense of their length. It is often observed in a common clothes line; most remarkably at sea, in the great tension of a ship's rigging during a rain storm, and in the relaxation when dry weather returns.

The amount of vapor in the air, is estimated with considerable accuracy by covering the bulb of a thermometer with a piece of linen or silk, and exposing it to the air, when the rapidity and extent of the fall of the mercury will indicate the amount of vapor.

Upon this principle, is constructed a little instrument,[§] called the Rosometer. It is a thermometer,[||] with a ball of black glass, the upper part of which, is covered with muslin; a little ether being dropped upon this part of the ball, dew soon begins to be deposited on the other, and the temperature at which this happens, is called the dew point.[*] Mr. Pollock of Boston constructs this instrument with two balls, one immediately below the other; the upper one is covered with muslin, and moistened with ether and the dew is deposited on the lower ball.

---

[*] Turner's Chem. p. 56. [†] Phil. Trans. 1818.

[‡] For Mr. Dalton's formula to correct this result, See Turner's Chemistry, first Eng. Ed. pa. 58.

[§] Invented by Mr. Jones of London, and Mr. Coldstream, of Leith.

[||] Filled either with mercury or alcohol.

EXPERIMENTAL ILLUSTRATIONS OF THE LAWS OF EVAPORATION.

1. *Loss of weight. Water balanced in scales, loses a perceptible weight in a short time;*—with alcohol and ether the effect is still more remarkable.

2. Heat applied to the fluid gives a much quicker result.

3. Camphor, carbonate of ammonia, and other very volatile solids, in the same circumstances, lose weight, although more tardily.

4. Dip a finger successively into water, alcohol, and ether, and observe that the sensation of cold, is stronger and quicker, the more evaporable the fluid.

5. *Production of cold. When the atmosphere is apparently still, we discover which way the wind is, by wetting the finger in the mouth and holding it up to the air,*—it will feel coldest on the windward side, the evaporation being there the most rapid, and consequently, heat being there most absorbed, from the finger, to form the vapor.

6. *Water is frozen by the evaporation of ether,*[†] *in the air;* this is conveniently done, by placing the water in a glass tube, sealed at one end; it may be one third or one half of an inch in diameter, and the water may occupy two or three inches in depth; a coiled wire may be pushed into the tube to lift the ice out, (and perhaps to aid by its conducting power, in the extrication of the latent heat;) if the water be colored, the effect will be the more pleasing; now let a capillary stream of ether, from a dropping tube or otherwise fall upon the tube containing the water, which may be either naked or may have a little gauze wrapped around it; in a few minutes the water will be frozen solid, and a momentary pressure of the tube in the hand will thaw the outside of the ice, so that it may be withdrawn by the wire.

7. *Cold produced by the Palm Glass.—Dr. Hare, from* 7 *to* 13.

"Two bulbs are formed, at each end of a tube, one having a perforated projecting beak.—By warming the bulbs, and plunging the orifice of the beak into alcohol, a portion of this fluid enters, as the air within contracts by returning to its previous temperature. The liquid, thus introduced, is to be boiled in the bulb which has no beak, until the whole cavity of the tube, and of both bulbs not occupied by liquid alcohol, is filled with its vapor."

---

[*] Phil. Trans. 1826—Edin. Phil. Jour. No. XVII. pa. 155.

[†] This fact was mentioned on p. 105.

"While in this situation, the end of the beak is to be sealed, by fusing it in a flame excited by a blow pipe."

"As soon as the instrument becomes cold, the vapor which had filled the space within it, vacant of alcohol in the liquid form, is condensed, and a vacuum is produced; excepting a slight portion of vapor, which is always emitted by liquids when relieved from atmospheric pressure."

"The instrument, thus formed, has been called a palm glass; because the phenomena, which it displays, are seen by holding one of the bulbs, in the palm of one of the hands."

"When thus situated, the bulb in the hand being lowermost, an appearance of ebullition always ensues in the bulb, exposed to view, in consequence of the liquid, or alcoholic vapor, being propelled into it from the other bulb subjected to the warmth of the hand."

"This phenomenon is analogous to the case of ebullition in vacuo, or the culinary paradox; but the motive for referring to the experiment here, is to state, that as soon as the last of the liquid is forced from the bulb, in the hand, a very striking sensation of cold, is experienced by the operator."

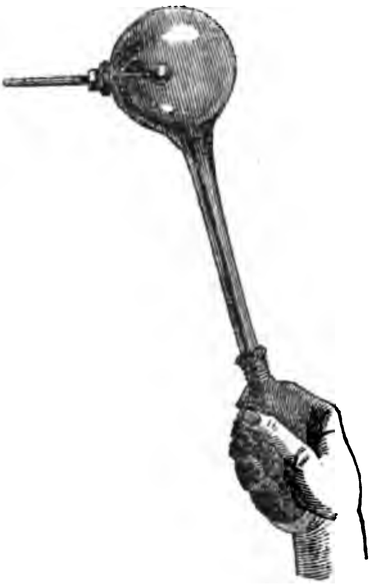
"This cold is produced by the increased capacity of the residual vapor for caloric, in consequence of its attenuation."

Remark.

A little ether dropped on either of the balls, immediately produces a rush of the fluid into that ball, and the other ball being then treated in a similar manner, the fluid as rapidly returns. The *appearance* of ebullition in the palm or pulse glass is evidently much increased by the fact that the thin film of fluid, lining the upper part of the ball, to which the hand is applied, is rapidly converted into vapor, drives the fluid before it, and then rushes through it; that there is no ebullition of the mass of the fluid, is proved by the fact, that if we reverse the position of the ball, placing it uppermost, and allow the fluid to rest in the palm of the hand it remains entirely quiet.

8. *Cold consequent to a relaxation of pressure.*

"It is immaterial whether a diminution of density, arise from relieving condensed air from compression, or from subjecting air of the ordinary density to rarefaction. A cloud similar to that which has been described as arising in a receiver partially exhausted, may usually be observed in the neck of a bottle recently uncorked, in which a quantity of gas has been evolved in a state of condensation by a fermenting liquor."



Apparatus for showing the influence of Relaxed Pressure, on the capacity of Air for Heat, or Moisture.

"A glass vessel with a tubulure and a neck, has an air thermometer, fastened air tight, by means of a cork into the former, while a gum elastic bag is tied upon the latter, as represented in this figure. Before closing the bulb, the inside should be moistened. Under these circumstances, if the bag, after due compression by the hand, be suddenly released, a cloud will appear within the bulb, adequate in the solar rays, to produce prismatic colors. At the same time the thermometer will show that the compression is productive of warmth—the relaxation of cold."

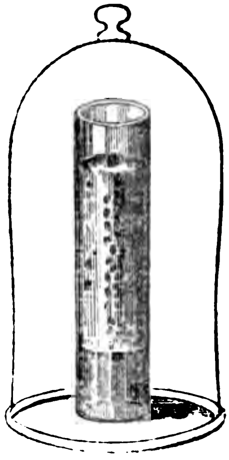
"The tendency in the atmosphere to cloudiness, at certain elevations, may be ascribed to the rarefaction which air inevitably undergoes, in circulating from the earth's surface to such heights."*

---

* In connexion with this effect on the transparency of the atmosphere, it may be interesting to recollect, the important influence of barometrical pressure on our health and comfort. If we were to regard (a supposition which is not exactly true, but which may be made for the sake of illustration,) the muscular power of the heart and arteries as a constant force, propelling the blood regularly in the circulation; then it is obvious, that the varying pressure of the atmosphere must necessarily affect both our feelings and our safety. With a diminished pressure, there must be a more rapid and hurried circulation, and with it we might expect faintness and oppression as is experienced on high mountains. The oppression and lassitude experienced in what is called a heavy air, (which is really a lighter air, our feelings alone being heavy,) is probably owing, in part, to this cause. At moderate elevations, we do not experience oppression, for there is generally a clearer and a cooler atmosphere, and our moral energy is invigorated by the scenery, and our physical force by the exercise. The subject is perhaps worthy of some attention in selecting situations for invalids, but many other causes must be taken into view, such as the exhalations, the temperature, &c.

9. *Influence of pressure on the escape of gaseous substances from combination.*

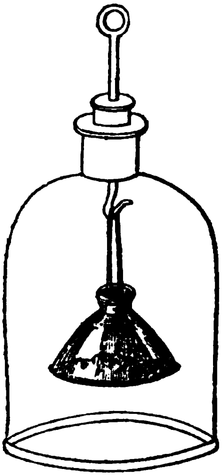
"When one of the ingredients of a Solid, or Liquid, is prone to assume the aëriform state, its extrication will be more or less easily effected, in proportion, as the Pressure of the Atmosphere is increased, or diminished."



"If a tall cylindrical jar, containing a carbonate undergoing the action of an acid, be placed under a receiver, and the air withdrawn by an air pump, the effervescence will be augmented. But if, on the other hand, the same mixture be placed in a receiver, in which the pressure is increased, by condensation, the effervescence will be diminished. In the one case, the effort of the carbonic acid to assume the gaseous state, is repressed; in the other, it is facilitated. Hence the necessity of condensation, in the process for manufacturing mineral water. Beyond an absorption of its own bulk of the gas, the affinity of the water is inadequate to subdue the tendency of the acid to the aëriform state; but when, by exterior mechanical pressure, a great number of volumes of the gas are condensed into the space ordinarily occupied by one, the water combines with as large a volume of the condensed gas, as if there had been no condensation."

If a gas, under the ordinary pressure of the atmosphere, will combine with water in the proportion of equal volumes, the pressure being doubled, the water will combine with two volumes of the gas, and if this last pressure be doubled, the volume of gas combined will be again doubled; that is, it will be quadrupled, compared with the first quantity combined under the ordinary atmospheric pressure, and so on. When thus charged, if suddenly relieved from all the extra pressure, by simply opening the vessel, as in drawing soda water, the fluid is violently agitated, because the gas that was forcibly combined, then resumes its elastic form.

10. *Cold produced by vaporization in vacuo.** *Water frozen by boiling ether.*



"Let a portion of water, just adequate to cover the bottom, be introduced into the vessel, represented in the subjoined drawing, as suspended within a receiver. Over the water, let a stratum of ether be poured, from an eighth, to a quarter of an inch in depth. If, under these circumstances, the receiver be placed on the air pump plate, and sufficiently exhausted, the ether boils and the water freezes."

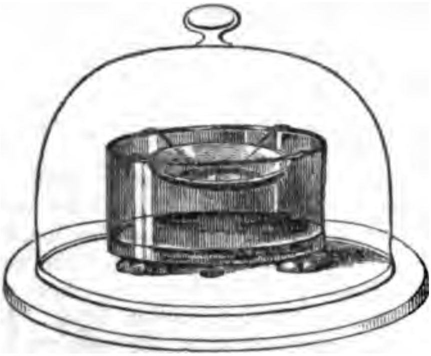
11. *Congelation of water in an exhausted receiver, by the aid of sulphuric acid.*

"In the preceding experiment, water is frozen by the rapid abstraction of caloric, consequent to the copious vaporization of ether, when unrestrained by atmospheric pressure. In vacuo, water undergoes a vaporization analogous to that of the ether in the preceding experiment; but the aqueous vapor evolved in this case, is so rare, that it cannot act against valves with sufficient force, to allow of its being pumped out of a receiver with the rapidity requisite to produce congelation. However, by the process which I am about to describe, water may be frozen by its own vaporization."

---

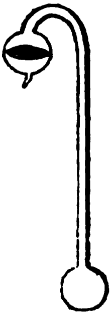
* This experiment is neatly performed by placing water in a watch glass upon a stand, and covering it with a thin metallic cup into which the ether is poured: on working the pump, the ether will boil, and the water will freeze; thus freezing and boiling are coincident, and the boiling is the cause of the freezing, and yet the boiling fluid is as cold as that which is freezing.

These experiments are more apt to succeed promptly if the ether be good; it is well to wash it two or three times with water in a bottle, in a mode to be described hereafter, and if the water which is used for freezing, has been just formed from melted ice or snow, it freezes so much the quicker as it has less sensible heat.



"A thin dish, or pane of glass, covered by a small quantity of water, and situated over some concentrated sulphuric acid, in a broad vessel, is placed on the air pump plate within a receiver, as represented in this engraving. Under these circumstances, the exhaustion of the receiver causes the congelation of the water."

12. *Wollaston's Cryophorus.*



"The adjoining figure represents the Cryophorus, or frost bearer; an instrument, invented by the celebrated Wollaston, in which congelation is produced in one cavity, by the rapid condensation of vapor in another."

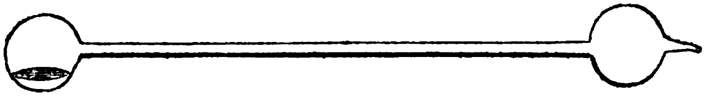
"In form, this instrument obviously differs but little from the palm glass, already described (46.) It is supplied by the same process, with a small portion of water, instead of alcohol; so that there is nothing included in it, unless water, either liquid, or in vapor."

"The Cryophorus being thus made, if all the water be allowed to run into the bulb near the bent part of the tube, and the other bulb be immersed in a freezing mixture, the water will freeze in a few minutes."

"So long as no condensation is effected, of the thin aqueous vapor, which occupies the cavity of the instrument, that vapor prevents, by its repulsion, the production of more vapor: but when, by means of cold, the vapor is condensed in one bulb, its evolution in the other, containing the water, being unimpeded, proceeds rapidly. Meanwhile the water becomes colder, and finally freezes, from losing the caloric which the vaporization requires."

"According to Wollaston, one grain of water, converted into vapor, holds as much caloric as would, by its abstraction, reduce thirty one grains from 60° Fahr. to the freezing point; and the caloric requisite to vaporize four grains more, if abstracted from the residual twenty seven grains, would convert them into ice.

13. *Large Cryophorus.*



"This figure represents a very large Cryophorus, the blowing of which I superintended; and by means of which I have successfully repeated Wollaston's experiment."

"This instrument is about four feet long; and its bulbs are about five inches in diameter."

VI. IGNITION OR INCANDESCENCE.

(*a.*) *Bodies become luminous in consequence of the accumulation of heat in them.**—In common language, this is expressed by saying that bodies become red hot, as a bar of iron does among burning coals.

Some bodies melt during their ignition; this is the fact with stones and most metals, and the melted stone or metal is as truly red hot as the bar of ignited iron. Some bodies evaporate during ignition; such are antimony, bismuth, lead and tin; some evaporate before ignition, as water and most fluids, not excepting the most fixed fluids, as quicksilver, and sulphuric acid, and dense oils; the latter are decomposed before ignition.

Gases do not become luminous at any temperature, although they may cause solid bodies, as gold, &c. immersed in them, to become luminous, the reason appears to be, that there is not matter enough in any one point to project the light to the eye, although from their communicating ignition to solid bodies, it is certain that they have the requisite heat.

Mr. Perkins' high steam, it would appear, is capable of igniting other bodies, (as already stated under steam and vapor;) it kindled tow and ropes, and it even ignited the bored orifice in the generator from which it was issuing; still it does not appear certain that it was itself luminous, nor is it certain that it was not, because we cannot inspect the steam formed in opake vessels, like those of metal, and when the steam issues into the air, it is no longer high steam; just at the orifice of emission, it is elastic and invisible, but a little way from it, it forms a cloud of mist.

(*b.*) *Bodies become luminous by friction.*—Glass, or agate, or quartz, held against a revolving gritstone or grindstone, become hot and luminous. Metals are affected in the same manner. The parts of gun locks and other pieces of steel emit sparks when held firmly against grindstones or revolving wheels, covered with emery powder spread upon oiled leather straps, which serve as bands to the wheels.*

---

* They are not supposed to undergo decomposition during their ignition.

(*c.*) *All bodies begin to shine by heat at the same temperature.*—This fact was first discovered by Sir Isaac Newton, and has been confirmed by others.

In general, redness, that is the emission of red rays, commences at about 800° of Fahr. and is fully established in broad day light at 1000° in the direct sun's light, perhaps about 1100°, or possibly 1200°. The appearance is of course much influenced by the quantity of the surrounding light. A body might be luminous in the dark, that would not be at all so in the light.

There are many cases of phosphorescence or emission of light which are not attended by any considerable increase of heat; these have been already mentioned under the head of light.

(*d.*) *A white heat is only a greater degree of ignition.*—White light, that is, light containing a due proportion of all the colored rays, is emitted when the accumulation of heat is the greatest; a welding heat of iron is a white heat. The artists have many terms to denote the various degrees of heat connected with their processes; thus, they speak of a cherry red, a worm red, &c. and of a white heat, a blue white, a red white, &c. and there are many degrees of heat between, commencing with the feeblest redness visible only in the dark, and ending with a full white light, distinctly visible even in the blaze of the meridian sun.†

(*e.*) *Ignition affords one of the strongest arguments for the identity of light and heat.*—If they are different substances or powers, then the heat when accumulated to a certain degree, expels the light, previously lodged in the body; or, it may be said, that as most cases of ignition are produced by burning bodies, the light from the fire enters the body along with the heat, and thus obtains a transit; or, if heat and light are merely modifications of each other, then it may be supposed that at a certain temperature heat becomes light, or possibly a certain accumulation or intensity of radiant heat affects the optic nerves so as to produce the sensation of vision.‡

---

* This is beautifully seen at the gun manufactory, at Whitneyville, near New Haven; the sparks fly off in innumerable tangents, and the hand, unless brought very near, may be held in the fiery stream without inconvenience; this is doubtless owing to the strong current of air which the revolution of the wheels produce. It is curious that while coarse emery is used, gunpowder is inflamed by the sparks at any distance to which they extend; but, when very fine emery is used, coarse gunpowder is not kindled, but if finely pulverized, it then flashes with the minutest sparks.—(Communicated by Mr. Eli Blake of Whitneyville.)

† Although it is called a white heat, there are more red rays than are contained in the sun beams.

‡ The very mild heat which causes the emission of light from some bodies, e. g. fluor spar, countenances the opinion that light is lodged in them; and light may be imparted to some bodies to such a degree, that they become partially transparent without producing, upon them, the effects of ignition; thus, eggs, the human fingers, and other bodies are illuminated, through and through, by an electrical discharge.

If we suppose that the entrance of heat continues to expel light from a body for an indefinite time, this difficulty is perhaps removed by adverting to the fact, already suggested, that at the temperature of ignition, the light enters the body along with the heat, and that both bodies thus find a transit through it. This however does not account for the indefinite ignition produced by friction; even allowing that it is indefinite, which has not yet been proved, there is no greater difficulty than attends the indefinite emission of heat under the same circumstances.

Perhaps it would not be useful, in a concise text book, to introduce the speculations of the learned and able philosophers who would make heat, and perhaps light, to depend upon the internal motions of the particles of bodies; one kind of effect depending upon supposed vibratory, or expansive, or retrocessive, and another upon gyratory motions of uncognizable particles.* We might quote the great names of Newton, Boyle, Hooke, Rumford, Davy, Leslie, and others. The question can perhaps never be decided; but in discussing the nature of light and heat, the statements of facts and the reasonings can be exhibited most conveniently upon the supposition that these agents are material, and that they are different from each other. This course may therefore be pursued provisionally, until other views shall be conclusively established.†

VII. CAPACITY‡ FOR HEAT, AND SPECIFIC HEAT.

(*a.*) *The capacity of a body for heat, is its power of containing a given quantity of heat at a given temperature.*§—The comparative estimate between different bodies is usually made, by taking them in equal weights; but it may be made also upon bodies in equal volumes; the numerical results will of course be different, but are capable of being intelligibly compared.

(*b.*) *The specific heat of a body, is the particular quantity of that power which it contains at a given temperature.*

---

* See Davy's Chemistry.

† See Dr. Hare's paper on the materiality of heat, Am. Jour. Vol. IV. p. 142, and the ingenious discussions between him and Professor Olmsted, in the same Journal, Vols. XI, XII, XIII. Dr. Hare has shewn that the phenomena of heat are inconsistent with the opinion that they depend upon corpuscular motion. There seems then to be no other alternative than that there must be a material cause of heat, although that cause is too subtle to be recognized by us in any other way than by its effects.

‡ The term is evidently figurative, and alludes to the capacity of a containing vessel. The use of the word, in relation to heat, implies merely a power, without deciding on the mode.

§ For a description of that elegant intrument, the *Calorimeter* of Lavoisier, see his elements, and most of the larger chemical works. The quantity of water obtained by the fusion of ice, during certain changes in bodies surrounded by that substance, was made the criterion of the quantity of heat; but there were some, perhaps inherent, sources of error, and the instrument is now very little, if at all used.

The experiments are commonly made by comparing fluids* or comminuted solids, after they have been mingled at different temperatures. That body which, in a given short time, has lost the greatest number of degrees, has the smallest capacity, and the smallest specific heat, and vice versa.

The resulting temperature is always nearest to that body, whose capacity or specific heat is the greatest, and therefore the greater the capacity the less the changes of temperature. Boerhaave first discovered this remarkable fact, with respect to quicksilver, and water, but Dr. Black first established the law; many other able men have investigated it, among whom are Wilcke, Irvine, Crawford, Lavoisier, Berard, and Delaroche, Petit, and Dulong, Clement and Desormes, &c.

(*c.*) *Different bodies, whether taken in equal weights, or volumes, contain different quantities of heat or caloric.*

This could never have been known by reasoning *a priori;* the conclusions are founded entirely upon experiment.

(*d.*) *Different bodies exposed to the same heating or cooling cause, undergo different changes of temperature, in equal short times, and the capacities are inversely as the change of temperature.* Thus fifty spheres, or cubes, equal either in weight or diameter, of as many different kinds of matter, if plunged into boiling water, and examined after an interval of five minutes, would be found very differently heated; or, if already arrived at the temperature of 212°, if they were exposed to a freezing air, and examined as above, they would be found very unequally cooled, although in the end, they would in both cases acquire a common temperature.

(*e.*) *In homogeneous bodies, mingled at different temperatures, the resulting temperature is always the arithmetical mean.*—A pint of water at 100°, and a pint at 200°, would on being mingled, give 150° as the resulting temperature, and the same would be true of any other fluids, or minutely divided solids.

(*f.*) *In heterogenous bodies, the resulting temperature is never the mean.*—The capacity of water is 23 that of mercury 1, for the changes which they undergo, when mingled at different temperatures, and in equal weights or volumes, are inversely as the changes they suffer.

One pint of mercury at 100° Fahr.+one pint of water at 40°,= not 70°, the arithmetical mean, but only 60°; the metal loses 40°, which raises the water only 20°; hence, in equal volumes, water has the greater capacity. If the pint of water be 100°, and the mercury at 40°, the temperature will be about 80°, because the water contains more heat than is necessary to raise the mercury to the mean.

---

* Always taking it for granted that they do not act chemically on each other.

Water 1 in volume, and mercury 2, = always the arithmetical mean; e. g. 70°, if the extremes be 100° and 40°; hence, in equal volumes, water has twice the capacity of quicksilver.

In equal weights, one pound of water at 100°, + one pound of mercury at 40° = 97½; therefore the 2½ lost by the water have raised the mercury 57½, which is in the proportion of 1 : 23, viz, water has twenty three times the specific heat that is contained in an equal weight of mercury, and its capacity is in the same proportion.*

(*g.*) *Formula.*—1. *By weight.*—If the weight be multiplied into the change of temperature, the capacity will be inversely as the change, that is, the greater the change, the less the capacity, and vice versa. 2. *By volume*; the capacity found as above, × into the sp. gr. = the capacity by volume.†

(*h.*) *Comparing classes of bodies, the capacities for heat are, in general, inversely as their density.*—Solids have less capacity than fluids—fluids less than gases, and vice versa.

When the capacity is enlarged, heat is absorbed, and when diminished, it is given out.

(*i.*) *The sudden expansion of air always produces cold.*—"This striking occurrence takes place on a vast scale at the fountain of Hiero; at the mines of Chemnitz, in Hungary. A part of the machinery for working these mines, is a perpendicular column of water, two hundred and sixty feet high, which presses on a quantity of air enclosed in a tight reservoir. The air is consequently condensed to an enormous degree by this height of water, which is equal to eight or nine atmospheres, and when a pipe, communicating with this reservoir of condensed air, is suddenly opened, it rushes out with extreme velocity, instantly expands, and in so doing absorbs so much caloric, as to precipitate the moisture it contains in a shower of very white compact snow, or rather hail, which may be readily gathered on a hat, held in the blast. The force of this is so great, that the workman who holds the hat is obliged to lean his back against the wall to retain it in its position. If the cock of the pipe is only partly opened, the snow is still more compact."‡

By condensing aëriform bodies into a small space, cooling them by freezing mixtures, and liberating them suddenly, great cold is produced by the rarefaction.

We have found occasion more than once to remark that similar effects probably happen in the higher regions of the atmosphere, from the sudden liberation of the ascending currents of rarefied air from pressure, and from their mixture with colder currents.

(*j.*) *Great and sudden increase of pressure upon common air, evolves so much heat as to ignite very combustible bodies.*—This was exhibited by a brass syringe, furnished at one end with a little chamber, containing tinder, agaric, or other combustible, which is heated by the compression produced by the quick stroke of the piston, so that the combustible, on being suddenly brought to the air, by the turning of a key, took fire. More recently, the combustible is contained in the piston itself, which, after the stroke, is quickly withdrawn from the tube. The instrument is now made of glass, which enables one to see the flash.

---

* Henry's Chemistry. The author quotes Dalton; the numbers usually stated are as 1 to 28.

† Murray.

‡ Aikin. I, 213.

(*k.*) *Changes of capacity for caloric have an intimate connexion with the regulation of natural and artificial temperature.*—The medium heat* of the globe is usually placed at about 50° of Fahr. and is found, as has been heretofore believed, at about 1000 feet below the surface of the ground.

Medium heat of the atmosphere at New Haven, about 50°.†
" " " the Torrid zone, 70° to 80°.
" " " moderate climates, 50° to 52°.
" " " near the polar regions, about 36°.

The extremes of the globe are from about — 50° sometimes — 70° to 100°, 105°, 110°; and even 120°, or perhaps in some situations, still more.

The extremes of artificial temperature are much greater, from — 91°, to 35127°, (*Henry.*) which is the highest estimated heat, but we know that it is not the highest heat that has actually been produced. We have no measure for it, and probably can never have any other than the effects which such heats produce in fusion, &c. The real zero has never been discovered.‡

(*l.*) *Freezing mixtures act by enlargement of capacity.*—A solid, as already observed, is always one ingredient in these compositions; it becomes fluid by uniting, chemically, with some other agent, and thus absorbs heat and produces cold. Salts and acids, as Glauber's, eight ounces, and muriatic acid, five ounces, are most commonly employed, and sink the thermometer from 50° to 0. When both ingredients are solid, the mixture is still more powerful, as in the case of muriate of lime and snow; and of muriate of soda and snow; by the former, mercury is frozen. Snow, or pounded ice, two parts, and common salt, one part, depress the thermometer from 50° to — 5°.§

The mere solution of a salt in water produces cold. Nitre, in large quantities, added to water, sinks the thermometer 17°; nitrate of ammonia, 28° ; muriate of lime three parts, and water two, 37° ; muriate of ammonia, and nitre in powder, with from five to eight parts of water, from 50° to − 11° ; and the salts, recovered by evaporation, answer as well as before.

---

* Should the views of Prof. Cordier, as to the increasing heat of the interior of the earth, be established, the result stated in the text cannot be correct; but it will require numerous and often repeated observations, extending to many countries, and through many years, to establish a conclusion so extraordinary —See Am. Jour. Vol. 15. p. 109.

† Pres. Day, in Trans. of Conn. Acad.

‡ We think it useless to reiterate the fruitless discussions on this subject; they may be found in all the larger chemical works. It is evident that no reliance can be placed upon the results, widely discordant as they are.

§ For a more copious table of freezing mixtures, see p. 136.

Diluted acids with salts, are more powerful than water only. Sulphate of soda, with sulphuric acid, diluted with as much water, reduces the temperature from 50° to 5°, and with diluted nitric acid, from 51° to 1°. With mixed salts the cold is still greater. Phosphate of soda, nitrate of ammonia, and diluted nitric acid, reduce the thermometer from 50° to −21°, and mercury has been frozen by a mixture of nitrous acid, sulphate of soda, and nitrate of ammonia.* By these, or similar means, all fluids have been frozen, except alcohol, and several of the gases have, by the aid of strong pressure, been condensed into fluids.

The salts should be previously well crystallized, and should retain their full proportion of water ; they should be well pulverized ; they should be mixed in vessels which are bad conductors of heat ; the access of the external air should, as much as possible be cut off, and the materials may be previously cooled by being placed separately in other freezing mixtures, taking care that they be not cooled below that degree at which the materials act on each other.†

(*m.*) *Many heat-producing, or calorific mixtures, act by diminution of capacity.*—Sulphuric acid and water combine with increase of specific gravity, and diminution of specific heat, and therefore with increase of sensible heat.

Many other acids, e. g. the nitric, muriatic, fluoric, &c. act in the same way ; even alcohol and water, in considerable quantities, grow sensibly warm by being mixed. The heat evolved in those cases in which the products of the chemical action are chiefly gaseous, does not appear to be well accounted for in this way. Nitric acid and oils, gunpowder and fulminating compositions generally, and mixtures of the chlorates with the combustibles, result in the conversion, more or less, of solids into aërial matter, and cold should therefore be generated, instead of heat, which is always evolved in great quantities.

Dr. Turner sums up our knowledge of specific heat under the following heads.

1. " Every substance has a specific caloric peculiar to itself, whence it follows that a change of composition will be attended by a change of capacity for caloric."

2. " A change of form, the composition remaining the same, is likewise attended with a change of capacity. It is increased when a solid liquifies, and diminished when a fluid passes into a solid."

3. " It is certain that the specific caloric of all gases increases as their density diminishes, and *vice versa.*

---

* Graham.

† Murray.

Mr. Dalton contends that this law prevails also in solids and fluids,[*] and Petit and Dulong have proved it with respect to several solids. The specific heat of Iron was found to be

			Centigrade.	Specific heat.
From	0	to	100°	0.1098
"	0	"	200°	0.1150
"	0	"	300°	0.1218
"	0	"	350°	0.1255

And so of other bodies.

	Spec. heats, from 0 to 100 cent.	Spec. heat from 0 to 300° cent.
Mercury,	0.0330	0.0350
Zinc,	0.0927	0.1015
Antimony,	0.0507	0.0549
Silver,	0.0557	0.0611
Copper,	0.0049	0.1013
Platinum,	0.0355	0.0355
Glass,	0.1770	0.1900

4. "Petit and Dulong have rendered it probable that the atoms of all simple substances have the same specific caloric."[†]

This is illustrated by a pretty copious table, for which see the Ann. de Chimie et de Physique, Vol. 10.

5. "A change of capacity for Caloric always occasions a change of temperature. An increase of the former is attended by a diminution of the latter; and a decrease of the former is attended by an increase of the latter."

The specific heat of the gases is an interesting problem. According to Dela Roche and Berard, several of them stand related as follows.

	Under equal volumes.	Under equal weights.	Specific gravities.
Atmospheric Air,	1.0000	1.0000	1.0000
Hydrogen Gas,	0.9033	1.2340	0.0732
Oxygen Gas,	0.9765	0.8848	1.1036
Nitrogen Gas,	1.0000	1.0318	0.9691
Nitrous Oxide,	3.3503	0.8878	1.5209
Olefiant Gas,	1.5530	1.5763	0.9885
Carbonic Oxide,	1.0340	1.0805	0.9569
Carbonic Acid,	1.2583	0.8280	1.5196

---

[*] Chem. Phil. part 1. p. 50.

[†] By comparing the equivalents of twelve principal metals, and of sulphur, as given by Petit and Dulong, and by Dr. Turner, in his Chemistry, it has been found that the product arising from the multiplication of those equivalents into the specific heat of the bodies, gives results so widely differing from uniformity, as "would seem to take all plausibility from the hypothesis that the atoms of simple bodies have the same specific heat."—*Bache, in Jour. Acad. Nat. Sci. Phil. Jan.* 1829.

Water being unity, the specific heats of the gases are as follows.

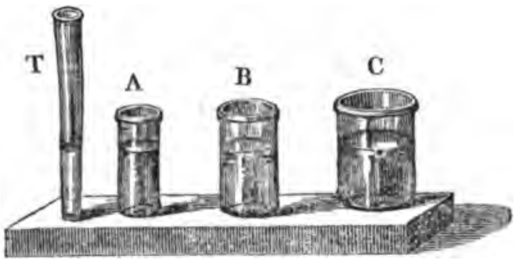
Water, - - - -	1.0000
Atmospheric Air,	0.2669
Hydrogen Gas, -	3.2936
Carbonic Acid,	0.2210
Oxygen Gas, - -	0.2361
Azote, - - - -	0.2754
Protoxide of Azote,	0.2369
Olefiant Gas, - -	0.4207
Oxide of Carbon,	0.2884
Steam, - - - -	0.8470

Specific heat of metals, according to Petit and Dulong.

Bismuth, - - -	0.0288
Lead, - - -	0.0298
Gold, - - -	0.0298
Platinum, - -	0.0314
Tin, - - - -	0.0514
Silver, - - -	0.0557
Zinc, - - -	0.0927
Tellurium, - -	0.0912
Copper, - - -	0.0949
Nickel, - - -	0.1035
Iron, - - - -	0.1100
Cobalt, - - -	0.1498
Sulphur, - - -	0.1880

It is worthy of observation that all the gases, excepting hydrogen, have, according to Petit and Dulong, less specific heat than water; this is the fact even with steam. It would seem that they had some doubts as to the correctness of this result.

Apparatus for illustrating capacities for heat.—Dr. Hare.



"Let the vessels A, B, and C, be supplied with water through the tube T, which commmunicates with each of them, by a horizontal channel in the wooden block. The water will rise to the same level in all. Of course the resistance made by the water, in each vessel, to the entrance of more of this liquid will be the same, and will be measured by the height of the column of water in the tube T. Hence if the height of this column were made the index of the quantity received by each vessel, it would lead to the impression that they had all received the same quantity. But it must be obvious, that the quantities severally received, will be as different as are their horizontal areas. Of course we must not assume the resistance exerted by the water within the vessels against a further accession of water from the tube, as any evidence of an equality in the portions *previously* received by them."

VIII. COMBUSTION.

(*a.*) *In common language it means the same as burning; that is, in most cases, the apparent consumption*[*] *of a body, and an entire change in its properties, with the emission of heat and light.*

(*b.*) *In what was called the new or French theory, combustion was synonymous with a combination of oxygen with a combustible body, attended by augmentation of its weight, and change of its nature, heat and light being at the same time emitted.*—Now, Chlorine is added as another agent possessed of similar powers with oxygen; also, by some, *Iodine;* and many even regard every case of intense chemical action, with the emission of heat and light, as combustion.

"Whenever the chemical forces that determine either combination or decomposition, are energetically exercised, the phenomena of combustion, or incandescence, with a change of properties, are displayed."[†]

In general we shall use the word combustion in its common and more restricted sense, taking due notice, however, of the other cases as we come to them.

(*c.*) *It would be premature to consider combustion fully at present;* for its theory and phenomena are best developed progressively as we proceed.

We mention combustion in this place merely to complete our list of the effects of heat; for, as commonly seen, it sustains a very close connexion with heat, since an exalted temperature is usually necessary to its existence. Heat is, however, often the consequence, as well as the cause of combustion.

(*d.*) *Phlogiston is a name formerly given to a principle of combustion, supposed to reside in all inflammable bodies;* dissipated, as was imagined, in the form of heat and light, during combustion; the body being thereby rendered uninflammable, and its inflammability being again restored by recombining with phlogiston, as when red lead is heated with charcoal which causes the incombustible metallic oxide to become again combustible in the form of metallic lead.

This theory[‡] is now obselete, but in its time, it rendered important service to the science of Chemistry, and was in vogue for a century. Phlogiston comes very near to the modern idea of combined and free caloric. If we substitute a combination of oxygen for the extrication of phlogiston, and the extrication of oxygen for the combination of phlogiston, we translate, very nearly, all the common cases of combustion, from one theory into the other.

---

[*] Sometimes the body remains, but in an incombustible state.

[†] Ure's Chem. Dic.

[‡] Invented by Becher, and more fully illustrated by Stahl.

APPENDIX TO CALORIC.

SEC. III. SOURCES OF HEAT AND COLD.

I. Sources of heat; *most of which are also sources of light.*

(*a.*) *The sun.*
(*b.*) *Combustion.*
(*c.*) *Chemical action without combustion.*
(*d.*) *Electricity and Galvanism.*
(*e.*) *Condensation of aëriform bodies by pressure.*
(*f.*) *Condensation of solids, by mechanical action, including friction and percussion.*
(*g.*) *Vital action.*

(*a.*) *The solar rays.*—The intensity of the solar heat being in proportion to the rays that can be collected upon a given spot, there appears to be no other limit to our power of generating heat in this manner, than what is found in the size of our instruments, and the difficulty of using them, for it has been long known, that the effect is much increased by lenses and mirrors.*

This is especially true if the focus be received on a black and rough surface, e. g. on charred cork lining a box, and covered by glass; thus a heat of 221°, was produced while the air was only 75°. —*Saussure.*—In another case, the heat generated by similar means, was from 230° to 237°, while a bright fire gave, at the same time, 212°.—*Black, Thomson.*

Dr. Hare remarks, that previously to the discovery of the heat excited by oxygen, by the compound blowpipe, or by the Voltaic series, there was no known mode of rivalling the heat produced by large burning glasses and mirrors. These have been already mentioned, perhaps sufficiently, in the account of heat and light.

It is not in our power to say what is the nature of the sun, and for aught we know, the popular opinion that his body is a globe of ignited matter, may be correct.†

(*b.*) *Combustion.*—After the solar influence, this is the most important source of heat; it is very completely under our command; it can be applied when and where we please, and varies from extreme mildness to extreme intensity. Common fires, in fire places and stoves; Argand's lamp; oil lamps; spirit lamps; gas lights; a smith's forge; the furnaces of the arts and of the laboratory; candles; the mouth blowpipe, and that fed by oxygen and hydrogen gases, are all familiar instances, in which combustion is seen.

---

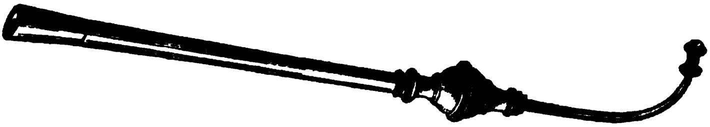
* Dr. Hare.

† Dr. Herschel's ideas of the nature of the sun, were peculiar. He supposed the sun's body to be opake; that his atmosphere has two strata of clouds; the one opake and the other phosphorescent; the latter he supposes to be the highest, and that they emit the light; that when the clouds are broken and ragged, the sun's opake body is seen through the clouds. The fruitfulness of different seasons he supposed to be connected with the quantity of light emitted from the luminous clouds of the sun.—*Phil. Trans.* 1801.

Combustion is mentioned with propriety, both as a source and as an effect of heat; for generally, it does not commence and proceed without an augmented temperature, and it raises the temperature in turn.

I shall omit the description of common furnaces, and subjoin that of the following instruments.

1. *The Mouth Blowpipe.—Dr. Hare,* 1 *to* 7.

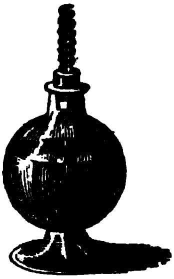


" As fire is quickened, by a blast from a bellows, so a flame may be excited by a stream of air propelled through it from the blowpipe."

" The instrument, known by the abovementioned appellation, is here represented in one of its best forms. It is susceptible of various other constructions; all that is essential being a pipe of a size at one end suitable to be received into the mouth, and towards the other end, having a bend, nearly rectangular, beyond which the bore converges to a perforation, rather too small for the admission of a common pin. There is usually, however, an enlargement, to catch the condensed moisture of the breath, as in this figure."

Berzelius has in an octavo volume, illustrating the extreme utility of the mouth blowpipe, with which Gahn discovered tin in a mineral containing only one per cent., which had escaped detection by analysis; and he extracted also copper from the ashes of a quarter of a sheet of paper.

2. *Lamp without a flame.*[*]



" About the wick of a spirit lamp, a fine wire of platina is coiled, so as to leave a spiral interstice between the parts of the spiral formed by the wire; a few turns of which should rise above the wick."

" If the lamp be lighted; on blowing out the flame, the wire will be found to remain red hot, as it retains sufficient heat to support the combustion of the alcoholic vapor, although the temperature be inadequate to constitute, or produce inflammation."

---

[*] See Am. Jour. Vol. IV. p. 328.

"Instead of blowing out the flame, it is better to put an extinguisher over it, for as short a time as will cause the flame to disappear. For this purpose, a small phial, or test tube, is preferable to the metallic cap usually employed."

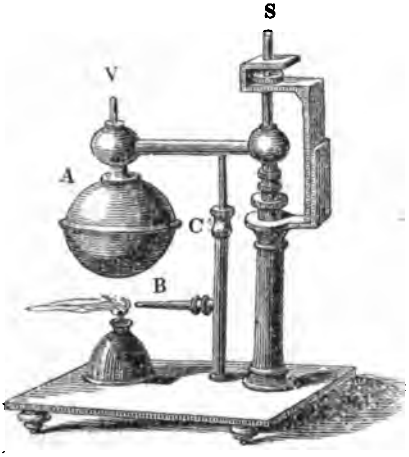
"The metallic coil appears to serve as a reservoir for the caloric, and gives to the combustion a stability, in which it would otherwise be deficient."

"There is some analogy between the operation of the wire, in acting as a reservoir of heat in this chemical process, and that of a fly wheel, as a reservoir of momentum, in equalizing the motion of machinery."

Dr. Hare introduced a blowpipe, in which the air was propelled by hydrostatic pressure; and in this manner he used also the oxygen and hydrogen gases.* I have found such a blowpipe very useful, and it will be mentioned again in this work.

The blowpipe of the enameler and of the thermometer maker, is fed by a double bellows, worked by the foot, and terminates in a pointed tube, which rises above a table, and thus supplies a lamp.

3. *Alcohol Blowpipe.*



"A flame resembling that of the enameler's lamp, may be produced by a small boiler, A, containing alcohol, in which alcoholic vapor is generated, as steam is, by the boiler of a steam engine."

"The vapor thus generated is substituted for air in the blast of the blowpipe, being directed upon the flame of a lamp in the same way, by means of a pipe proceeding from the boiler, and terminating in a beak, with a capillary orifice, B. the boiler is furnished with a safety valve, V."

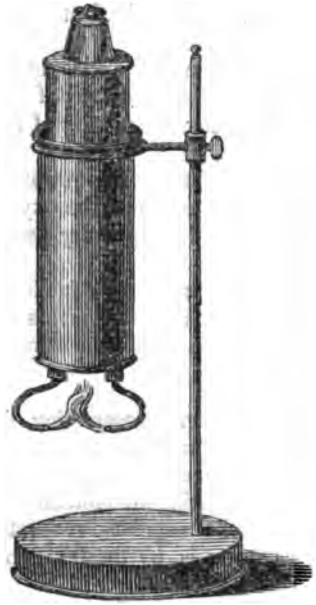
"It may be objected to flame thus excited, that as the oxygen is not so copiously supplied, as when a stream of air is used, the oxide of lead in flint glass tubes is reduced by it, and the glass consequently blackened."

"The apparatus here represented, is furnished with an adjusting screw, S, by which the height of the boiler is regulated; while the communication is preserved between it and the beak, by means of a tube sliding through a stuffing box, C, which surmounts a larger tube to which the beak is soldered."*

---

* See his Compendium, p. 73.

4. *A new modification of the Blowpipe by Alcohol.*



"This figure represents an improved blowpipe, by alcohol. In the ordinary construction of that instrument, the inflammation is kept up, by passing a jet of alcoholic vapor through the flame of a lamp, supported, as is usual by a wick. The inflammation of the jet cannot be sustained without the heat of the lamp flame; since the combustion does not proceed with sufficient rapidity to prevent the inflamed portion from being carried too far from the orifice of the pipe; and being so much cooled by an admixture of air, as to be extinguished. By using two jets of vapor in opposition to each other, I find the inflammation may be sustained without a lamp. If one part of oil of turpentine, with seven of alcohol be used, the flame becomes as luminous as a gas light."

"In order to equalize and regulate the efflux, I have contrived a boiler like a gasometer. It consists of two concentric cylinders, open at top, leaving an interstice of about one quarter of an inch between them; and a third cylinder, open at bottom, which slides up and down in the interstice. The interstice being filled with boiling water, and alcohol introduced into the innermost cylinder, it soon boils and escapes by the pipes. These pass through stuffing boxes in the bottom of the cylinder. Hence their orifices, and of course the flame, may be made to approach to or recede from the boiler. It must be obvious that the introduction of the alcohol requires the temporary removal of the intermediate cylinder."

---

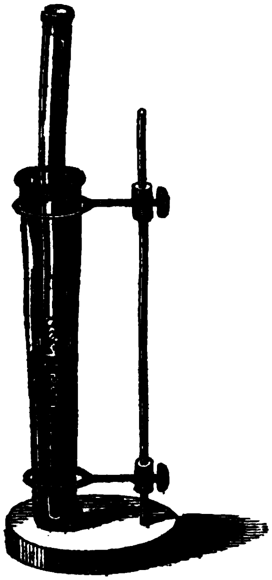
* "Stuffing box is the technical name given by mechanics to a small hollow metallic cylinder, in which, by means of another cylinder acted upon by screws, some cotton, tow, leather, or other elastic substance, is packed about a rod, so as to allow it to move to and fro without permitting any fluid to escape from the vessel into which it may enter."

(c.) *Chemical action without combustion;* that is to say, without combustion to begin with; combustion is not used as a means of raising the heat, although this mode of evolving heat may end in combustion, provided any ingredient in the mixture is combustible; e. g. as in the case of nitric acid acting on alcohol or oils, dense or volatile. Fermentation of hay may produce combustion.

Spontaneous combustions proceed in many instances, from chemical action, as in cases where oils, tallow, paints, and similar substances, are in contact with flax, cotton or hemp. Tanner's bark and horse manure, by fermentation, produce heat for the green house, and for some processes in the arts.

Most of the cases under this head belong to capacity and specific heat, and the doctrine has been partly anticipated. Many more instances will follow. At present I add only the following from Dr. Hare.

5. *Boiling heat produced, by the mixture of sulphuric acid with water.*



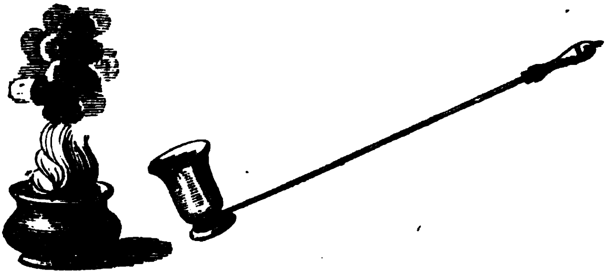
"Into the inner tube, represented in the adjoining figure, introduce about as much alcohol, colored, to render it more discernible, as will occupy it to the height of three or four inches. Next pour water into the outer tube, till it reaches about one third as high as the liquid within; and afterwards add to the water, about three times its bulk of concentrated sulphuric acid. The liquid in the inner tube will soon boil violently, so as to rise in a foam."

6. *Chemical combination, attended by decomposition, as the means of evolving caloric.*

"Instances of that species of corpuscular reaction, which comes under this head, will be hereafter mentioned in their proper places. The extrication of caloric, which is usually more or less a consequence of intense chemical reaction, is a collateral, rather than a necessary consequence of it.

"As an example in which caloric is rendered sensible, by the method in question, the inflammation of turpentine by a mixture of nitric acid, with sulphuric acid, may be adduced."

"The inflammation of alcohol, or oil of turpentine, by means of a chlorate and sulphuric acid, as represented by this figure, affords another exemplification perfectly in point."



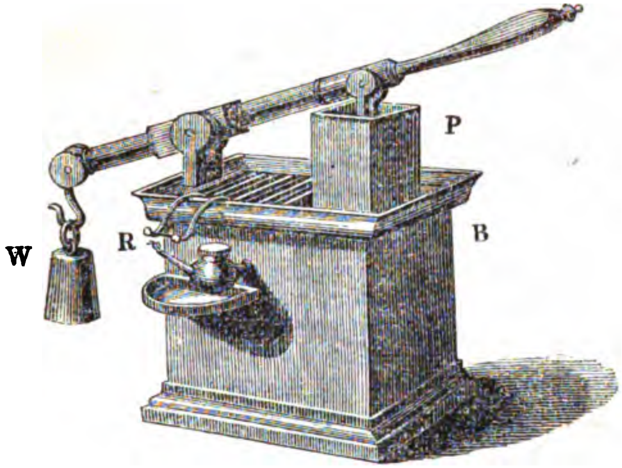
"About as much chlorate of potash as may be piled upon a half cent, being deposited in a heap, in the inflammable liquid, and concentrated sulphuric acid being poured upon the heap, the liquid is inflamed."

"As portions of the liquid are sometimes projected into the air, in a state of inflammation, it is expedient, for the security of the operator, to have the glass, used to convey the acid, fastened to the end of a rod."

(*d.*) *Electricity and Galvanism.*—The modes of excitement are peculiar; generally they are well known, but they belong either to a different science, or to a different part of this science.

The applications of the heat evolved in this way, are extremely useful to the chemist; the power is conveyed, conveniently, into and through the interior of vessels, and thus gives us a furnace heat without its inconveniences. The heat is mild or intense at pleasure; no heat, probably not even that of lightning, exceeds that produced by electrical and galvanic arrangements. The decomposing powers connected with common and galvanic electricity, produce the most curious and important results, dividing the material world between the opposite poles, but this part of the subject is not appropriate to the present topic. The facts and the instruments relating to Galvanism are reserved for another place, except that I shall introduce here from Dr. Hare, an instrument equally simple and useful.

7. *The galvanophorus, or galvanic substitute for the electrophorus.*



"The preceding figure represents an instrument for igniting a lamp, by means of a galvanic discharge, from a calorimotor."

"The plunger, P, being depressed, by means of the handle attached to it, some acid, contained in the box, B, is displaced, so as to rise among the galvanic plates. By the consequent evolution of the galvanic fluid, a platina wire (fastened between the brass rods forming the poles of the calorimotor, and projecting over the lamp, as seen at R,) is rendered white hot, and a filament of the wick, previously laid upon it, is inflamed."

"The weight, W, acts as a counterpoise to the plunger, and keeps it out of the acid, when it is not depressed by the hand."

(*e.*) *Condensation of aëriform bodies by pressure and cold.*—This topic is already anticipated under specific heat and vapors. Vapors and gas mechanically condensed, as by the syringe and piston, give out heat; vapors impart heat to colder bodies, as in the distilling apparatus with its condenser, already mentioned. Compressed oxygen and chlorine give out light, and these gases are said to be the only simple ones that become luminous by pressure.

(*f.*) *Condensation of solids by mechanical action including friction and percussion.*—The flint and steel in collision, or two quartz stones struck forcibly together; any hard stone firmly held upon a revolving grit stone; the vigorous rubbing together of two sticks; the friction of branches of trees in stormy weather; of axles in carts and wagons and of various parts of powerful machinery; of the axles in sheaves or blocks of running tackle[*] on board of ships; of ropes, passing rapidly over a gunwale, as when a whale is harpooned; friction in the boring of cannon and muskets; of a rope running rapidly through the hand; of the hand rubbed on a stair rail, or on one's woolen coat sleeve; all these and many others are instances of heat evolved on this principle.

The rotary match box gives sparks by the collision of a rapidly revolving steel with flint, and a similar instrument called the steel mill, was used to give light in coal mines before the invention of the safety lamp.

An iron bar grows hot enough, by vigorous hammering, to kindle shavings, and lead will by the same treatment kindle phosphorus.

Wood, in rapid revolution, "may be carbonized throughout the circle of contact, by holding against it another piece properly sharpened, and one cork rubbed against another will become hot enough to kindle phosphorus."[†] A disk of soft iron rapidly revolving by machinery, will easily cut in two[‡] the hardest steel saw plate, or the best file.

(*g.*) *Vital action.*—This is evidently a source of heat, although in a way not perhaps fully understood. There can be no doubt that oxygen, acting in respiration, is an important agent in producing and sustaining it; it appears probable also that secretion, connected with the influence of the nerves, is concerned, and some facts countenance the opinion that galvanic agencies are not dormant.

Whatever may be usefully said on the latter subject, belongs to a more advanced stage of this work.

II. THE SOURCES OF COLD.

1. Evaporation,
2. Rarefaction,
3. Chemical action.

1. *Evaporation.*—The general facts on this subject have been already stated. Whenever a body passes to the aëriform state, it absorbs heat to turn it into vapor, and thus cools the contiguous bodies. Sensible cold is produced by the evaporation of water, more by that of alcohol, and most of all by that of ether or carburet of sulphur, or liquid sulphurous acid, whether measured by our organs or by the thermometer. We have already seen that water is frozen by the evaporation of ether, both in the exhausted receiver of the air pump, and in a tube in the atmosphere. The mercury in a thermometer ball, wet with water and having a current of air blowing upon it, will fall 5°; if with alcohol, 12°, and if with ether, 30°.—*Murray.*

---

[*] See Lt. Glynn in Am. Jour. Vol. XIV, p. 196, and Capt. Parry's 2d Voyage, New York Ed. p. 212. "The weight of the ice every moment increasing, obliged us to veer on the hawsers, whose friction was so great as nearly to cut through the bit heads, and ultimately set them on fire, so that it became requisite for people to attend with buckets of water."—*Parry.*

[†] Dr. Hare. [‡] See Am. Jour. Vol. VI, p. 336.

With a rapid exhaustion by the air pump, mercury in a thermometer ball, if the ball be wrapped in flannel or fleecy hosiery and dipped n ether ior sulphuret of carbon, will be frozen in two or three minutes.

Evaporation is very extensive in its natural operation, and its universal prevalence is one of the great causes which prevents the accumulation of heat on our globe, and which therefore tends very much to preserve the equilibrium of its temperature. It is also occasionally of use in the operations of art, and is sometimes employed as we have already seen, to depress the temperature of particular bodies.

2. *Rarefaction.*—This is intimately connected with evaporation, and depends upon the same principle. As condensation produces heat, so rarefaction generates cold. It is seen chiefly in the aëriform fluids. The remarkable example at the fountain of Hiero, has been already mentioned. In air pump experiments, the thermometer falls several degrees, and Dr. Darwin observed, "that if, in the stream of air issuing from the receiver of an air gun, in which it had been compressed, a thermometer were placed, it sunk from 5° to 7°."

In the first instance, it produces heat by its condensation, and instantly after, cold by its rarefaction.

Air, condensed into a reservoir and suddenly liberated from an orifice, produces a considerable degree of cold: Gay Lussac found it equal to 50° of Fahr.*

If heat must be absorbed in evaporation or gazification, in order to produce an aëriform body, more heat is required to enlarge its bulk after it is produced, and, as its particles are repulsive, when the pressure which retains them within a certain distance is diminished, the particles recede and caloric is absorbed, for, otherwise their repellent power could not be maintained at increasing distances, and they would again approach; when they are forcibly brought together anew by compression, the heat is again given out.

3. *Chemical action.*—Cold is produced during the chemical action of those substances whose capacity is by the union enlarged, and which therefore absorb caloric. The immediate effect of chemical union is a mutual penetration of particles, and therefore an increase of specific gravity, and of course an emergence of heat; but it often happens also that there is an enlargement of capacity and the absorption of heat which follows from this cause, is frequently sufficient to generate a considerable degree of cold. Sulphuric acid and snow afford us an illustration of both these remarks; when first mingled they produce heat for an instant, owing to the energy of their combination, but immediately after, cold is produced because water is of the capacity of ten for caloric, while ice is only nine.

---

* Probably from the medium of temperature. "The cold will, however, depend on the previous condensation of the air." Dr. Torrey informs me that he makes this experiment with Newman's blowpipe, and that, with an air thermometer, the effect can be witnessed at a considerable distance.

TABLE OF FREEZING MIXTURES.

Frigorific mixtures with ice.

Mixture	Parts	Thermometer sinks	
Snow, or pounded ice Muriate of soda	2 parts 1	Thermometer sinks from any Temperature. to — 5°	*
Snow, or pounded ice Muriate of soda Muriate of ammonia	5 parts 2 1	to — 12°	*
Snow, or pounded ice Muriate of soda Muriate of ammonia Nitrate of potassa	24 parts 10 5 5	to — 18°	*
Snow, or pounded ice Muriate of soda Nitrate of ammonia	12 parts 5 5	to — 25°	*
Snow Diluted sulphuric acid	8 parts 2	From + 32° to — 23°	55°
Snow Muriatic acid	8 parts 5	From + 32° to — 27°	59°
Snow Diluted nitric acid	7 parts 4	From + 32° to — 30°	62°
Snow Muriate of lime	4 parts 5	From + 32° to — 40°	72°
Snow Cryst. muriate of lime	2 parts 3	From + 30° to — 50°	82°
Snow Potassa	3 parts 4	From + 32° to — 51°	83°

N. B.—The reason for the omissions in the last column of this Table, is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.

The second column indicates the lowest degree of the thermometer, whatever may be the temperature of the materials on mixing.

Combination of Frigorific mixtures.

Mixture	Parts	Thermometer sinks	
Phosphate of soda Nitrate of ammonia Diluted nitric acid	5 parts 3 4	Thermometer sinks From 0° to — 34°	34°
Phosphate of soda Nitrate of ammonia Diluted mixed acids	3 parts 2 4	From — 34° to — 50°	16°
Snow Diluted nitric acid	3 parts 2	From 0° to — 46°	46°
Snow Diluted sulphuric acid Diluted nitric acid	8 parts 3 3	From — 10° to — 56°	46°
Snow Diluted suphuric acid	1 part 1	From — 20° to — 60°	40°
Snow Muriate of lime	3 parts 4	From + 20° to — 48°	68°
Snow Muriate of lime	3 parts 4	From + 20° to — 54°	64°
Snow Muriate of lime	2 parts 3	From — 15° to — 68°	53°
Snow Cryst. muriate of lime	1 part 2	From 0° to — 66°	66°
Snow Cryst. muriate of lime	1 3	From — 40° to — 73°	33°
Snow Diluted sulphuric acid	8 parts 10	From — 68° to — 91°	23°

N. B.—The materials in the first column, are to be cooled, previously to mixing, to the temperature required, by mixtures taken from the preceding tables.—*Graham, p.* 391.

SEC. IV. ATTRACTION.*

By attraction, we mean the tendency of bodies to approximate, and also the unknown cause of that tendency.—In its most general sense, it extends to atoms and masses reciprocally, and to every distance.

It is the bond of the universe; it appears to depend in general on no proximate cause, but to emanate at once from the will of the Deity.

Counteracted and modified by the powers of repulsion and projection, it keeps every thing in harmonious equilibrium.

It is unknown whether it arises, in all its varieties, from the modifications of one cause, or whether there are several, giving origin to the different kinds of attraction.

However this may be, it is most convenient to consider the subject under different heads.

1. GRAVITATION.
2. MAGNETISM.
3. GALVANIC ELECTRICITY.
4. COHESION AND AGGREGATION.
5. CHEMICAL ATTRACTION OR AFFINITY.

1. GRAVITATION.

(*a.*) *It extends to every thing, to all quantities of matter, and to all distances.*

(*b.*) *Its force is directly as the quantity of matter, and inversely as the square of the distance.*—The quantity of matter, in different cases, being as 1. 2. 3. 4, the attracting force at a given distance, will be as those numbers directly; but the same body being placed successively at the distances 1. 2. 3. 4, the attracting force will be expressed inversely, by 1. 4. 9. 16, that is, at the distance 2 it will be $\frac{1}{4}$, at 3, $\frac{1}{9}$, and at 4, $\frac{1}{16}$, as great as it was at the distance 1.

We are familiar with the effects of gravitation, and therefore regard them as natural; they are so to our habits, but only in obedience to an established law; if the law had been different, our habits would have been accommodated to it.

Were there no attraction towards the earth, a stone thrown into the air would not return, and would stop only from the resistance of some medium, or of some other body which it might encounter.

(*c.*) *The projectile power modifies the gravitating force,* so that the planets move in elliptical orbits, and neither fall to the centre of motion, nor move off in tangents to the curve of the orbit.

---

* I have been accustomed to give, in my lectures, a very general sketch of the different varieties of attraction, that affinity may be the better understood, and shall pursue the same course in this work.

2. MAGNETISM.

(*a.*) *This is a power usually manifested in iron or steel*, after having received particular treatment, or after having been for some time in a particular position.

(*b.*) *It belongs also to nickel*, and to cobalt, which like nickel, is found to be the more magnetic, the purer it is made.

(*c.*) *Magnetism resides also in the earth.*—The magnetic poles are not coincident with the poles of revolution. In the Arctic region, the magnetic pole is* in 69° 16′ of N. lat. and 98° 8′ W. lon.†

(*d.*) *Repulsion as well as attraction is predicable of magnetism.*

(*e.*) *Similar magnetic poles repel, and opposite poles attract.*

(*f.*) *Magnetism is connected, in some mysterious manner, with the other imponderable powers, light, heat, and electricity.*

(*g.*) *The solar rays, especially the violet, magnetize a needle.*‡

(*h.*) *The calorimotor evolves heat with great energy, but its electricity is of a very low intensity; still, it magnetizes needles powerfully, when there is no light perceptible.*

(*i.*) *Similar effects, in a greater or less degree, are produced by all the varieties of galvanic apparatus;* all the known imponderable fluids being occasionally present together.

(*j.*) *We cannot say, therefore, whether magnetism is a distinct power, or a property or appendage of one or more, or of all the other imponderable powers.*—The magnetic power, both in its attractions and repulsions, is pleasingly exhibited by magnetic needles, fish, boats, and balls, by the horse shoe magnet, bar magnet, &c. Many articles of iron and steel become magnets spontaneously, especially such as have stood long vertically or nearly so, and more especially, if in the magnetic meridian. Magnetism is excited also by rapid rotary motion.

3. GALVANISM

1. *Requires, and will receive a distinct statement near the end of this work*, but as this remarkable power actually arranges in a natural method, all the elements and compound principles of matter, it is mentioned here among the general powers.

(*a.*) *Mode of excitement.*—Nearly as various as matter, almost all substances of different natures, or sometimes the same substance in different conditions, arranged in a particular connexion, will serve to render this power perceptible. Common electricity is also excited in many ways, but most usually by the friction of glass or resin.

---

* Or was at the time of Captain Parry's late voyages: I know not whether any observations have since been made, to ascertain its constancy in latitude; the variations of the needle E. and W., seem to prove that the magnetic pole varies in longitude.

† Am. Jour. Vol. XVI, p. 149.

‡ Morrichini's and Mrs. Somerville's experiments on magnetizing needles, are said to have failed in skilful hands; it is suggested that the needles might have been magnetized before. The editor of the Philos. Magazine, new series, Vol. IV, p. 221, thinks that, at least, the magnetism was increased.

(*b.*) *Mode of exciting the Voltaic power.*—Certain combinations of metals, usually zinc and copper, with fluids, especially saline and acid fluids, producing opposite polarity at the two extremes of the series.

(*c.*) *Mode of receiving and transmitting the power.*—By conductors, uniting the poles; they are commonly wires, and are often pointed with well prepared charcoal.

(*d.*) *Nature of the power.*—It has been commonly regarded as the same with electricity; like that it is attended by light, heat, and magnetism, variously modified and combined in different proportions, in different kinds of apparatus; so that one predominates in one kind and another in another. It is clear that it is not electricity merely.

(*e.*) *Sensible and demonstrable effects.*—Attractions and repulsions, as in common electricity; similar poles repelling and opposite attracting. All elements and all compound principles, when placed in the electro-galvanic circuit, being for the time endued with polarity, chemical decompositions are thus produced. Muscular shocks are also among the effects produced by this power, as well as light, heat, and magnetism, which have been already mentioned.

(*f.*) *Mode of effecting the decompositions*, by bringing the connecting points into contact with the particular substance.

(*g.*) *Classification of the elementary bodies.*—Oxygen, iodine, and chlorine, are attracted to the positive pole, and are therefore said to be electro-negative.

The combustibles and metals are attracted to the negative pole, and are therefore said to be electro-positive.

(*h.*) *Classification of the principal proximate principles in the compound bodies.*—The acids go to the positive pole; the earths, alkalies and oxides of metals, to the negative.

(*i.*) *Galvanic electricity is a powerful agent in decomposition;* it is more energetic, and it is also more manageable than common electricity.

(*j.*) *The arrangement of the principles of bodies under this power*, will be mentioned as we come to them individually.

(*k.*) *The other effects are not material in our present state of advancement;* they will be mentioned in their proper place.

It is supposed, that the electrical and magnetic attractions are governed by the same general law with gravitation.

4. Cohesion—adhesion—aggregation.

(*a.*) *Cohesion is a union of parts, without change of properties.*—The particles of a bar of iron cohere; this force gives the iron its strength; those of water cohere but feebly; hence it has no strength; those of moist dough cohere more than water, &c. These are examples of union where the minutest parts are of imperceptible magnitude.

Adhesion.[*]—Two plates of glass or two of metal, or one of glass and one of metal, when moistened or oiled, adhere, with considerable force; with still more force, two leaden hemispheres made by splitting a bullet, and pressing the surfaces together with a wringing or twisting motion. If furnished with hooks, the parts of the bullet may be suspended, and will support a considerable weight that may be gradually increased for some time, before the hemispheres will part.[†]

(*b.*) *The cohesion of homogeneous*[‡] *particles is often termed aggregation*, and masses made up in that manner are said to be aggregates.

(*c.*) *The word adhesion may be used to denote the union between surfaces of perceptible magnitude, whether similar or dissimilar in their nature.*

(*d.*) *Cohesion produces augmentation of volume, and frequently a change in form, but no change in properties.*—The dust of marble is the same substance with the stratum or mountain of marble which afforded it; it contains the same elements, and in the same proportions. The elements are united by affinity or chemical attraction; the compound particles produced by the union of the elements, are united by cohesion.

(*e.*) *Adhesion of surfaces of perceptible extent produces no change in properties.*—Generally the union of such surfaces is feeble. That particular mode of corpuscular union which is called cohesion, is the source of the different strength of materials, as of lead, iron, wood, &c.

(*f.*) *The attraction which produces the union of particles is often called corpuscular attraction.*—It is quite immaterial whether the particles be simple, as those of single metals, or compound as those of metallic alloys or wood; in either case, the state of the body results from the union of minute particles, which are for this purpose regarded as mechanically simple, whether chemically so, or not.

The union of dissimilar particles, as will be hereafter seen, is referred to chemical action. Chemical union may first connect dissimilar particles, as zinc and copper; and the compound, which is in that case called brass, is composed of particles, that are regarded as mechanically simple, and are called integrant particles; while the others are called constituent particles.

---

[*] *Adhesion* is merely a word of convenience; the power that unites surfaces of perceptible magnitude, and that which unites particles in aggregation, is doubtless the same.

[†] This effect evidently depends, in part, upon the furrows on the surface of the lead which are brought into close contact by the twist that is given in pressing them together, with a screwing motion; when polished, it is difficult to make them adhere.

[‡] Heterogeneous particles will also unite, but the result is not an aggregate; it is a new body, whose particles are connected not by mechanical, but by chemical attraction.

(G.) **CRYSTALLIZATION IS THE RESULT OF THE ATTRACTION OF AGGREGATION.**

(*h.*) *A crystal is a symmetrical solid, produced by the union of integrant particles.*[*]

(*i.*) *Natural crystals are numerous, and art produces many more;* every good mineral cabinet exhibits great numbers of the former, and every good chemical collection of the latter.

(*j.*) *Destruction or great diminution of the power of cohesion is an indispensable preliminary.*—This is effected either by solution in a fluid, or by the aid of heat producing fluidity or the state of vapor. In the former case, it is necessary to drive off part of the solvent by heat; in the latter, merely to allow the fluid to cool, or the vapor to be condensed, in order that crystals may be formed. Certain circumstances are, however, necessary to be attended to in order to success. If the solvent be very rapidly expelled by the aid of a high temperature, or, if the fused body be suddenly exposed to an intense cold, either a shapeless mass will be formed, or only confused and irregular crystals. In general, fine crystals are obtained only by slow evaporation and by slow cooling. Water and most of the metals are examples of bodies that crystallize by a mere reduction of temperature. A saturated solution of sulphate of soda, boiled and corked in that state, does not become solid on cooling, but on letting in the air; agitating it by a jerk or jar, or dropping in a crystal, it congeals and heat is evolved, sufficient to melt it again. If a string or mark be placed on the neck of the vessel, it will be seen that the mass has been expanded by the crystallization. It does not appear that it is the *mere pressure of the air*, as was formerly supposed, that produces the crystallization; the air seems to act as a disturbing force, or perhaps by the introduction with it, of some foreign body, which may serve as a nucleus.[†] A gentle waving motion does not cause it to congeal. The salts are crystallized generally by diminishing the quantity of the solvent, that is, by evaporation, or by conjoining both, diminishing the solvent by evaporation and reducing the temperature; or, when a particular portion of a salt has been suspended by the aid of an elevated temperature, a simple reduction of temperature is sufficient, without evaporation. For, an elevated temperature increases the power of most solvents. Common salt, however, being dissolved in nearly equal quantities by cold as by hot water, no advantage is gained by the aid of heat, except in speed, nor does a reduction of temperature cause it to crystallize. The only method in which this can be effected, is by diminishing the solvent by evaporation. It is found that crystallization is much facilitated by supplying a nucleus; and Le Blanc, a Parisian apothecary, has even founded upon it a method of obtaining large and beautiful crystals, by selecting the best, replacing them in the solution, and turning them daily, as the lower side does not increase.

---

[*] That is of particles of the same kind, but these particles may be chemically, either simple or compound.

[†] A point or almost any solid frequently determines incipient crystallization; so a jar or sudden vibratory motion brings the particles into such a position, that their polar attractions become effectual, and the negative pole of the galvanic series produces crystallization, while the positive pole counteracts it. Light also causes camphor to crystallize from its alcoholic solution, and it is redissolved in a dark day.—*Dr. Ure.*

(*k.*) *An increase of bulk is commonly an effect of crystallization, but sometimes the bulk is diminished*, as in the case of mercury. Substances which have been deposited from an aqueous solution, generally retain, intimately combined, a portion of water, which is called their *water of crystallization.* The efficacy of freezing mixtures is owing, in a considerable degree, to this water of crystallization, which, by becoming fluid, absorbs caloric; when, with the aid of heat, it causes the salt to become fluid, the salt is said to suffer the *aqueous fusion.* When it escapes spontaneously, into the atmosphere, the salt is said to *effloresce*, for the crystalline form is destroyed, and it falls into powder. When the salt attracts water from the air, and becomes more or less fluid, it is said to *deliquesce.*[*] When it splits and crackles by heat, it is said to *decrepitate.*

(*l.*) All bodies, in crystallizing, assume a determinate form. Thus the crystal of alum is an octahedron; that of common salt a cube; of the beryl, a hexahedral prism, &c. It must not be understood, however, that these forms are invariable. The same substance will sometimes assume one form, sometimes another, according to circumstances. But, to this *apparent* caprice there is a limit, for a given substance will always crystallize in one of a given number of forms, which are appropriate to it.

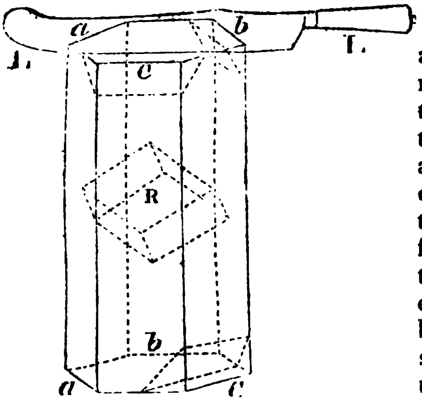
Prisms and pyramids are among the most common forms of crystals, but they admit of great diversity.

(*m.*) *All the forms of crystals are reducible either by dissection or by calculation, to six primitive forms*, namely, the hexahedron, including the cube, parallelopipedon and rhomboid; the regular octahedron; the prism of six sides; the regular tetrahedron; the dodecahedron with rhomboidal faces, and the dodecahedron with isosceles triangular faces. This very curious subject has been developed by the successive labors of Romé de L'Isle, Gahn, Bergman, Bournon, and Haüy. Haüy completed what Bergman had begun, by extracting the primitive form of calcareous spar in the following manner.

---

[*] Sometimes portions of the fluid from which crystals have been precipitated, are lodged mechanically between the plates, and it may be even a portion of a fluid containing a different substance, if other salts or compounds were present in the solution.

Dr. Hare, Fig. 1 *to* 14.

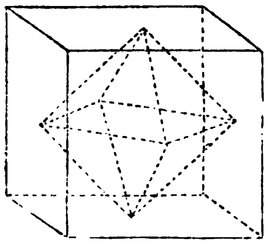


"As each of the sides of an hexagonal prism of calcareous spar, is bounded by two edges, one at each end of the prism; there are six edges at each end, and in all, twelve edges. If to every one of the twelve edges a knife be forcibly applied, in the direction indicated in figure 1, one of the edges, *a b c*, *a b c*, bounding each side, will yield so as to expose a smooth natural facet, making an angle of 45° with the adjoining side. The alternate edges will not split off so as to present surfaces corresponding either in smoothness, or obliquity, with those above described, so that the six facets will be equally divided between the two ends of the prism, each having three facets alternating with three remaining edges."

"If the dissection be continued, by applying the knife in directions parallel to the facets, finally a rhomboid R will be developed, which exists not only in the hexagonal prism, but in many other crystalline forms of calcareous spar."

"All these other forms are called secondary. The rhomboid, which is their common nucleus, or primitive form, is beautifully exemplified in the Iceland spar."

FIG. 2.



"The same author teaches us that a cubic crystal of fluor spar, can be split only in directions parallel to the faces of an octohedral nucleus, whose situation, relatively to the containing cube, is represented by figure 2."

"By various dissections, analogous to those which have been adduced, it is rendered highly probable that every crystallizable substance has an appropriate form, which it assumes in the first instance, and which is the basis of all its other forms."

"The nuclei may sometimes be obtained by percussion, sometimes by heat; in other cases by heat followed by refrigeration."

"Although a nucleus cannot be extracted in every instance from crystals, the existence in them of primitive forms, is usually inferred by analogy. The angles which the sides make with each other, are always the same in a nucleus, however obtained; and such crystals are always divisible in directions parallel to all their surfaces, whereas there are some surfaces of secondary forms, parallel to which, by cleavage, new facets cannot be obtained."

"Haüy enumerates six primitive crystalline forms, the parallelopiped, (including the cube, rhomboid, and four sided prism,) the regular tetrahedron, regular octohedron, hexahedral prism, rhombic dodecahedron, and dodecahedron with triangular faces."

Fig. 3.—*Quadrangular or four-sided prism.*

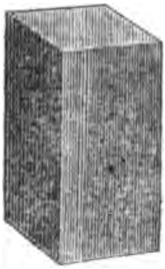


Fig. 4.—*Cube.*

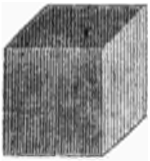


Fig. 5.—*Rhomboid.*

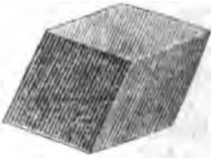


Fig. 6.—*Tetrahedron.*

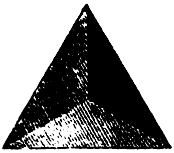


Fig. 7.—*Octohedron*

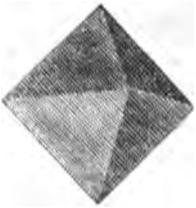


Fig. 8.—*Hexangular or six sided prism.*

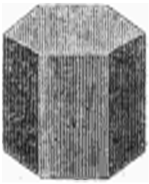
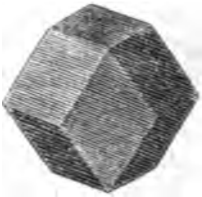


Fig. 9.—*Rhombic dodecahedron.*



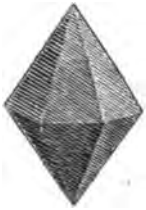


FIG. 10.—*Dodécahedron with triangular faces.*

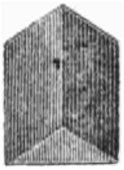


FIG. 11.—*Triangular or three sided prism.*

"The primitive forms, by a further dissection of the octohedron, hexangular prism, and dodecahedra, in directions, not parallel to the sides, may be reduced into three forms: the tetrahedron, or simplest solid, the triangular prism, or the most simple prism; and the parallelopiped, including the cube, rhomboid, and four sided prism. As it is in size only, that integrant atoms can be altered by cleavage; it it is inferred that if the dissections were continued until the smallest integrant atom should be developed, its form would be the same as that of the parent mass. Hence also the inference has arisen, that the only forms, which belong to integrant atoms, are those above mentioned."

It is remarkable that (the sphere and spheroids only being excepted,) these three forms are the simplest of solids. As three lines are the smallest number that can include a superficies, so four planes are the smallest number that can include a solid; the integrant molecules above named have successively, four, five, and six faces.

(*n.*) *The actual or secondary forms are built up, by the union of integrant particles, to produce the primitive form, and then by the addition of other particles, single or in groups, upon the faces of the primitive form.*

(*o.*) *The developement of these processes, constitutes the theory of crystallization, proceeding according* to the laws of decrement.

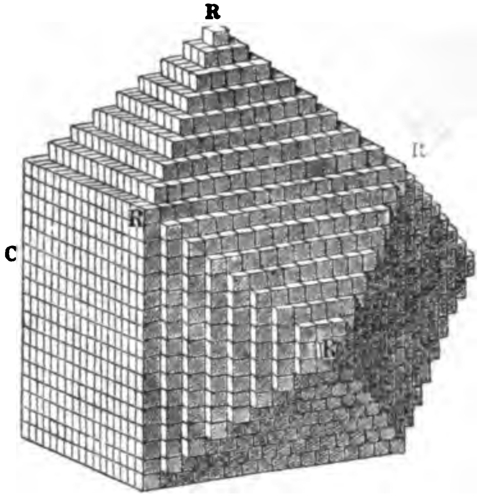
1. Parallel to the edges—2. Parallel to the diagonal—3. Parallel to a line intermediate between the side and the diagonal; or, parallel to either of the above, but proceeding by three in breadth, and two in height, or the reverse, or by such a ratio that the relation of height and breadth, in the ranges of particles, shall be expressed by a proper vulgar fraction; this supposed arrangement of integrant particles is called—4. Mixed decrement.

(*p.*) *A minute consideration of this subject, belongs to mineralogy* but the following illustrations will render the descriptions of increment and decrement intelligible.

Conversion of a cube into a dodecahedron.

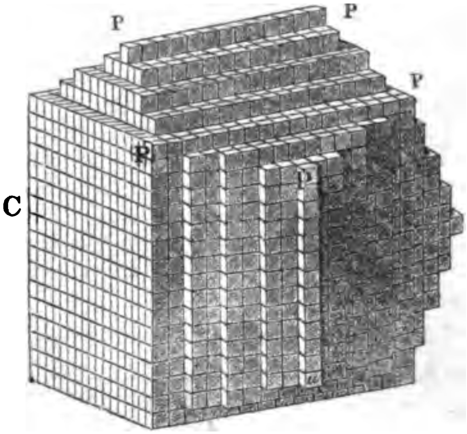
"If a cube be increased by layers of particles, applied to all its sides, the edges of the layers being parallel to those of the cube, and each layer being made less than that immediately preceding it, by one row of particles on each of its edges, a dodecahedron, or twelve sided solid, with rhombic faces, will be produced."

Fig. 12.



"If, instead of diminishing every layer one row, on every edge, they be made less, at each addition, by two rows on two parallel edges, while, upon the other two edges, each layer is made alternately the same as the preceding, alternately less by one row, a dodecahedron, or twelve sided solid, with pentagonal or five sided faces, will be produced."

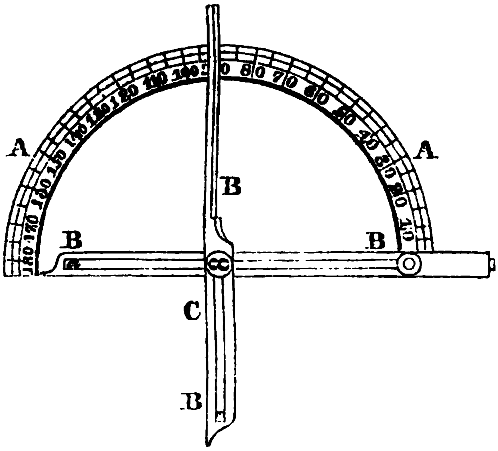
Fig. 13.



"One surface (C) of the cube, in each figure, is represented as if no addition were made to it, in order that the situation of the nucleus, relatively to the pyramids raised upon it, may be understood. It must be evident that each rhombus, **R R R R**, in fig. 12, and pentagon, **P P P P P**, in fig. 13, is made up of the surfaces of two adjoining pyramids, built upon a cubic nucleus."

"The decrements may proceed only on two sides, or a diminution of two, three, or more rows may take place on all the sides; yet in either case, secondary crystalline forms may be built upon the common nucleus, or primitive form."

Fig. 14.—*Of the Goniometer, or instrument for measuring the angles of crystals.*



"The goniometer is founded upon the 15th proposition of Euclid, which demonstrates that the opposite angles, made by any two lines in crossing each other, are equal. Hence it follows that the angles made by the legs **B B**, **B C B**, of this instrument, fig. 14, above and below the pivot on which they revolve, are equal to each other.—Consequently, if they be made to close upon any solid crystalline angle, presented to them at C, they will comprise a similar angle on the other side of the centre about which they turn. This angle is evidently equivalent to that of the crystal, and is ascertained by inspecting the semicircle A, graduated into 180 degrees precisely in the same manner as a protractor."

"The construction of goniometers is usually such as to allow the legs to be detached from the arch, in order to facilitate their application to crystalline angles; and yet, so that they may be reapplied to the semicircle, without deranging them from the angle to which they may have been adjusted."

"The piece of brass, in which the pivot is fastened, slides in a slit in each leg, so as to permit them to be made of the most suitable length, on the side on which the crystal is applied."

The reflective Goniometer of Dr. Wollaston, depends upon the reflection of the rays of light from the brilliant surfaces of contiguous crystalline plates, uncovered by cleavage, or of natural surfaces. The pieces or crystals to be examined are fixed upon an axis whose revolution carries around a graduated wheel, which measures the angle contained between two contiguous surfaces, when they have arrived successively in the position to reflect an image of the bar of a window or of some other definite line.* This instrument is much more accurate than that of Carangeau, used by Haüy, (See the figure above,) and has corrected a number of errors, some of which were important.

Mr. Daniell has contrived a method of discovering the structure of crystals by solution. In a mass of alum lying in water, there will be discovered, after some time, upon its lower part in high relief, both octahedral forms and sections of octahedra.—Borax gives similar results. Even shapeless metals, which a peculiar tendency to crystallization, will reveal their crystalline forms by the action of acid solvents; bismuth exhibiting with dilute nitric acid, cubes, antimony, rhomboidal plates, and nickel, regular tetrahedra.†

Very different views of crystallization are taken by more recent authors, among whom Mr. Brooke‡ and Professor Mohs§ are the most distinguished. Crystalline forms that have an intimate connexion with each other, are considered as forming certain natural groups or systems of crystallization. They are called, the tessular system which comprehends the cube, the tetrahedron, the regular octahedron, the rhombic dodecahedron, &c.; the pyramidical system, containing the octahedron with a square base and the right square prism; the prismatic system including the rectangular and rhombic octahedron, and the right rectangular and right rhombic prisms; the hemiprismatic system, embracing the right rhomboidal and the oblique rhombic prisms; the tetarto-prismatic system containing the oblique rhomboidal prism, and the rhombohedral system comprehending the rhombohedron and the regular hexagonal prism.||

This complex system seems to present no advantage to compensate for the absence of the simplicity and perspicuity which characterizes the system of Haüy.

---

* A more particular description with a plate may be found in Phillips' Mineralogy.
† English Jour. Sci. Vol. I. p. 24.
‡ Familiar Introduction to Crystallography.
§ Treatise on Mineralogy, translated by Mr. Haidinger.
|| Turner, 2d Ed. p. 555.

It is worthy of observation, that Professor Mitscherlich of Berlin, in 1819,* discovered "that certain substances are capable of being substituted for each other in combination, without influencing the form of the compound. The neutral phosphate and biphosphate of soda, have exactly the same form as the arseniate and binarseniate of soda; the phosphate and biphosphate of ammonia with the arseniate and binarseniate of ammonia, the biphosphate and binarseniate of potash; each arseniate has a corresponding phosphate, possessed of the same form and containing the same number of equivalents of acid, alkali and water, and differing in nothing but in one's containing arsenic, and the other phosphoric acid."

It appears then that certain substances, when combined in the same manner with the same body, are disposed to assume the same crystalline form, and this discovery has given origin to the phrase isomorphous crystals. The arseniates are isomorphous with the phosphates; the oxide of lead and baryta and strontia form isomorphous salts with the same acid. The isomorphous crystals appear to contain the same quantity of water† of crystallization, and there are many other very curious circumstances in the constitution of these bodies, which are too minute to be introduced into this work, but which are thought to give great support to the atomic theory to be mentioned hereafter.

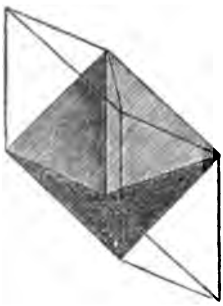
THEORY OF DR. WOLLASTON.

It has been already remarked, that among solids bounded by plane faces, the tetrahedron, the triangular prism, and the cube, are the simplest; these are the three integrant molecules of Haüy, and it would seem that their simplicity and their capability of being so arranged as to produce, perhaps, all other solids, afforded a strong presumption in favor of their being the real integrant particles of bodies. But a different view has been taken of this subject by Dr. Wollaston; for this reason among others, that in "crystallograpy we meet with appearances which Haüy's theory but imperfectly explains. A slice of fluor spar, for instance, obtained by making two successive and parallel sections, may be divided into acute rhomboids; but these are not the primitive forms of the spar, because by the removal of a tetrahedron from each extremity of the rhomboid, an octohedron is obtained. Thus, as the whole mass of fluor may be divided into tetrahedra and octohedra, it becomes a question which of these forms

---

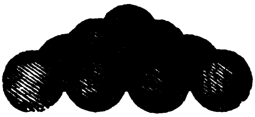
* Ann. de Chimie and de Physique, Vol. XIV, p. 172, XIX, p. 350, and XXIV, pp. 264 ard 355, Turner.

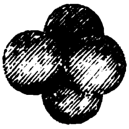
† And when the quantity of water is different, the crystals assume a different form.—*Turner*.

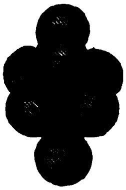


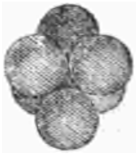
is to be called primitive, especially as neither of them can fill space without leaving vacuities, nor can they produce any arrangement sufficiently stable to form the basis of a permanent crystal."

"To obviate this incongruity, Dr. Wollaston (*Phil. Trans.* 1813,) has very ingeniously proposed to consider the primitive particles as spheres, which, by mutual attraction, have assumed that arrangement which brings them as near as possible to each other. When a number of similar balls are pressed together, in the same plain, they form equilateral triangles, with each other; and if balls so placed were cemented together, and afterwards broken asunder, the straight lines in which they would be disposed to separate, would form angles of 60° with each other. A single ball placed any where on this stratum, would touch three of the lower balls, and the planes touching their surfaces would then include a regular tetrahedron. A square of four balls, with a single ball resting upon the centre of each surface, would form an octohedron; and upon applying two other balls at opposite sides of this octohedron, the group will represent the acute rhomboid. Thus the difficulty of the primitive form of fluor, above alluded to, is done away, by assuming a sphere as the ultimate molecula. By oblate and oblong spheroids, other forms may be obtained."*









Dr. Wollaston has demonstrated, geometrically, that by assorting spheres and spheroids in particular groups and modes, all the solids of crystals may be constructed. The cannon balls in an arsenal, are often arranged in such a manner as to illustrate this subject. One group forms a square and another a triangle, and by piling them

---

[*] Brande, quoted by Hare.

they become pyramids, shewing half a tetrahedron, half an octohedron, &c. which would be completed, by continuing the group downward, in the same form. The marbles used for play, by children, may be made use of for similar illustrations. But it is obvious that the truth of this view, beautiful and probable as it is, cannot be demonstrated, nor is it perhaps inconsistent with that of Haüy; for if the ultimate integrant particles of bodies are spheres or spheroids; as they may, by the supposition, be grouped so as to produce Haüy's integrant molecules, and these may be the last term of mechanical analysis, although the ultimate particles of which they are composed, may be spheres; and when they are inconceivably small, there will be no appreciable difference between the plane and curved faces. Indeed, in Haüy's theory, the passage by increment and decrement, is supposed to be by particles so minute, that the steps cannot be ordinarily perceived, although the imperfection of the process sometimes renders them more or less obvious.*

5. Chemical attraction or affinity.

(a.) *It is exclusively, a corpuscular power.*

(b.) *Its three principal characteristics,* are: it is exerted at insensible distances; between particles only; and those particles are always heterogeneous.

(c.) *Its effects are, a change of properties more or less complete:* it is unlike cohesion, which induces no change of properties, but merely of bulk or form.

(d.) *The change of properties, in the cases where weak affinities are exerted, is often slight; giving in many instances only the modified properties of the parent substances;* as examples, we can mention watery solutions generally, as of salts, gum and sugar, and often alcoholic solutions, as of resins; and among fluids, alcohol and water, and water and acids; the union in such cases, is quiet, and attended with no remarkable appearances.

(e.) *But the union is permanent and cannot be destroyed by mechanical means.* Solutions of salts, sugar, gum, and alcohol, in water, are instances in point; they are not decomposed by repose, by agitation or by filtration, thus proving that the union is not merely mechanical.

(f.) *This class of compounds should be considered as midway between mere aggregation and energetic chemical combination;*—The union is chemical, inasmuch as it is not subverted by mechanical means; but these compounds partake of the nature of aggregates, inasmuch as they present the mitigated properties of the parent substance and no new properties.

---

* Mr. Daniel, in a paper in the Eng. Jour. of Science, Vol. I, p. 24, has with great ability, illustrated Dr. Wollaston's theory; but the limits of this work do not allow us to go farther into these *metaphysics of crystallization;* a subject which is perhaps more closely allied to mechanical than to chemical philosophy.

(*g.*) *Mere mechanical mixtures are separated by mechanical means;* muddy water becomes clear by filtration and by repose, which have no effect upon salt water.

(*h.*) *Energetic chemical action produces an entire change of properties.* Oxygen and hydrogen have no resemblance to water or to each other; nitric acid and potassa none to salt petre; muriatic acid and soda none to common salt; potassium and oxygen none to potassa and so on, in a thousand cases more. Inert substances produce active compounds, as in sulphuric acid; active principles inert compounds as in sulphate of potassa; compounds containing an energetic principle or principles, retain a degree of activity, sometimes great, as nitrate of silver and many other metallic salts, and arseniate of potassa; inert principles produce inert compounds, as in borate of magnesia, and in a word, there is great variety in the results, so that they cannot be predicted, and can be learned from experiment only.

(*i.*) *Colors are produced,* and different colors by different proportions of the same materials. The metallic oxides and salts, red lead, oxide of mercury, the chromates of lead, natural and artificial, and the two sulphurets of mercury and of arsenic, are examples.

(*j.*) *Colors are destroyed.*—Chlorine destroys nearly all colors, and the sulphurous acid many.

(*k.*) *The specific gravity is changed, and generally increased.*—Compounds of ammonia and the acid gases are precipitated in the form of solid salts; but some of the metallic alloys are lighter than the mean specific gravity of the metals combined;* and some gaseous combinations form other gaseous compounds that are lighter, but in general aëriform bodies by combining, undergo condensation.†

(*l.*) *Temperature, or sensible heat, is changed.*—It is *increased,* as when alcohol and water, sulphuric acid and water, oxygen and combustibles, sulphur and metals, iodine and phosphorus, are united.

It is *diminished,* as by solution and by all freezing mixtures.

(*m.*) *The form of bodies is changed.*

Solids become fluid, as in the freezing mixtures; also Glauber's salts and nitrate of ammonia rubbed together.—*Webster.*

Fluids become solid, as water in slaked lime, and in nearly all crystals.

Solution of strong muriate of lime, decomposed by strong sulphuric acid is precipitated solid; most acids by combining with different bases produce solids, provided water is removed by evaporation.

Gases become liquid.—Oxygen and hydrogen form water.

---

[*] The constituent particles may have approximated and the integrant particles receded, so that the fact involves no impossibility.

[†] In olefiant gas, the elements in a state of freedom would occupy four volumes instead of one.

Gases become solid.—Acid gases and ammonia precipitate solid salts, (*vide k.*)

Solids become gas.—Several ammoniacal salts, properly decomposed, are converted into aëriform bodies; this is true, particularly of the nitrate and muriate of ammonia.

Fluids become gas.—Water decomposed by galvanism with gold or platina wires affords oxygen and hydrogen gases in mixture.*

(*n.*) *A very minute division of matter is effected by chemical union.* It is much more minute than any mechanical means can produce; nitrate of silver discovers the slightest trace of muriatic acid: so ammonia detects any salt of copper; hydriodic acid platinum; recent muriate of tin and green sulphate of iron discover gold.

(*o.*) *Cohesion resists chemical action.*—Therefore as a preliminary it is diminished, by the mechanical operations of pounding, rasping, grinding, &c. and by previous chemical operations, as when caustic potash is fused with refractory gems and stones, to prepare them for solution in acids. Marble in lumps, dissolves slowly in acids, but in powder rapidly,—so of salt, sugar, &c.

(*p.*) *Affinity is not universal.*—Water does not dissolve siliceous sand, nor resins, nor oil, nor clay; these bodies may be mixed with water by mechanical agitation, but they will separate again by repose, or by filtration or other mechanical means.

(*q.*) *No body, elementary or compound, is without affinities.*—Siliceous sand unaffected by water, is dissolved by caustic potash; resin by alcohol, oil by alkali, common clay, in part, pure argil entirely, by sulphuric acid.

(*r.*) *Solution is only a particular case or mode of chemical action and union.*—It takes place generally, between solids and fluids; but is also predicable of the other forms of matter; gases dissolve solids and fluids, and these in turn absorb gases.

(*s.*) *Solution is generally promoted by heat.*—In the cold, 4oz. of water do not dissolve 3oz. of sulphate of soda, but heat enables the whole to be readily dissolved.—*Henry.*

(*t.*) *The solubility of different substances, in the same fluid, is very different.*—$\frac{1}{2}$oz. sulphate of ammonia, $\frac{1}{3}$oz. sulphate of soda, $\frac{1}{16}$oz. of sulphate of potash, and $\frac{1}{500}$ of sulphate of lime, are dissolved in 1oz. distilled water.—*Id.*

(*u.*) *Heat generally promotes chemical action;* as is commonly said, and in most cases truly, by diminishing the power of cohesion, as is seen in the solutions of solids; but this explanation would hardly apply to the explosion of gunpowder, and of fulminating powders. Sometimes cold brings on chemical action; sea water, containing muriate of soda, and sulphate of magnesia, is said to undergo double decomposition, at the freezing temperature, producing sulphate of soda, and muriate of magnesia.* It cannot be doubted, that electric and galvanic agencies are frequently developed by heat, and that thus chemical action is often induced.

---

* Many important chemical events depend on condensation or evolution of gases; explosions are often produced by the latter.

(*v.*) *A modified degree of heat is necessary.*—Red precipitate is formed at or near the boiling heat of mercury, but it is decomposed by ignition, and both its oxygen and metal are recovered.

(*w.*) *Chemical action is often brought on by mechanical means.*—Several of the fulminating powders, and the mixtures of the chlorate of potash and combustibles, explode by a blow, by friction, and pressure; which favor, at once, the approximation of the particles within the sphere of attraction, and the developement of heat which favors the chemical action.

(*x.*) *No approximation, short of imperceptible distance, will bring on chemical action.*—The negative is established by the approximation of any kind of matter towards any other for which it has an affinity; as for instance, a drop of nitric acid on a glass plate, will be indifferent to silver or copper filings pushed *near* to it, but the action commences when apparent contact is established. When sulphur and mercury are in apparent contact, there is no action, but it is brought on by rubbing them together. Sulphuric acid will run to the bottom of alcohol, and produce action only at the touching surfaces, but it is quickly brought on, in the entire mass, by agitation. Agitation of fluids and solids, to make them mingle quickly, promotes their action, as in the case of common salt and water.

(*y.*) *Even apparent contact is often insufficient, and solution becomes necessary.* Hence, the old maxim, "corpora non agunt nisi sint soluta." Tartaric acid and carbonate of soda, dry quicklime and dry muriate of ammonia, dry nitrate of copper, wrapped in tinfoil—in each of these cases there is no action till moisture is supplied, when it comes on vigorously.

(*z.*) *Bodies having no affinity are sometimes brought to unite by a third body.*—Oil and water, by the intermedium of caustic alkali, form soap.

(AA.) THE FORCE OF AFFINITY IS DIFFERENT BETWEEN DIFFERENT BODIES.

Were it otherwise, there would be no decompositions, except by the effect of the imponderable agents.

(BB.) ELECTIVE AFFINITY IS THE FIGURATIVE EXPRESSION OF THE PREFERENCE WHICH ONE BODY IS SUPPOSED TO MANIFEST FOR ANOTHER, TO THE EXCLUSION OF A THIRD.

The alcoholic solution of camphor is precipitated by water, which unites with the alcohol, and the camphor may be redissolved by the addition of more alcohol.

---

* Aikin's Dict. Vol. II. pp. 389, and 779.

The acetate of lead is decomposed by sulphuric acid; the nitrate of silver, by copper; nitrate of copper, by iron; nitrate of mercury, by copper; muriate of soda, by sulphuric acid; and so in instances innumerable. In all these cases, except the first, there is a new salt formed by the addition of the decomposing body, the acid or base of the preceding salt being liberated.

(CC.) *In such cases, therefore, a compound of two principles is decomposed by a third, which unites with one, and excludes the other,* which may be thus illustrated; $A+B=C$. D unites with A, and forms the compound $A+D$, or with B, and forms the compound $D+B$, B in the first case, and A in the second, being excluded. If any solid appears, it is called the precipitate, and the decomposing body, the precipitant; the fluid is called the solution.

(*dd.*) *In some cases, a weaker affinity is compensated by an increased quantity of the feebler ingredient.*—Muriate of soda 2, oxide of lead 1, there is no effect in twenty four hours; but with muriate of soda 1, and oxide of lead 3 or 4, decomposition follows in twenty four hours, and muriate of lead is formed, and soda, or its subcarbonate, evolved; this fact is the foundation of the manufacture of soda from common salt. The solution of sulphate of copper is blue, but if the muriatic acid is added largely, the color changes to green, indicating a decomposition, and the production of a muriate of copper.

(EE.) DOUBLE ELECTIVE AFFINITY, IS WHERE TWO COMPOUNDS, EACH CONSISTING OF TWO INGREDIENTS, ARE DECOMPOSED, FORMING TWO NEW COMPOUNDS.—A, composed of $B+C$, is mixed with D, composed of $E+F$; the result may be, $B+E$, or $B+F$, or $C+E$, or $C+F$. Important decompositions, otherwise unattainable, are often effected in this manner.

(FF.) DECOMPOSITIONS STILL MORE COMPLEX, INVOLVING THE ACTION OF SEVERAL AGENTS, EACH CONSITING OF TWO OR MORE PRINCIPLES, MAY PRODUCE SEVERAL DECOMPOSITIONS, AND SEVERAL NEW COMPOUNDS.—Many of the processes in the animal and vegetable economy, are of this description, and some among minerals.

(GG.) *Extraneous circumstances and forces influence chemical action*, among which the chief are *quantity*, *cohesion*, *insolubility*, *gravity*, *elasticity*, *efflorescence*, *temperature*, *mechanical pressure*, *and electricity*.

1. *Quantity of matter* exerts an important influence on chemical decompositions. This is a well known practical fact. In dissolving a salt in water, the first portions added, are more readily dissolved than subsequent ones, and the energy of attraction* diminishes as we approach the point of saturation.

---

* Or is it *mechanical obstruction* that retards the solution; the *degree* of affinity remaining the same ?—(*Communicated.*)

So, in decomposing compound bodies, either by affinity, or heat, the last portions are sometimes separated with much greater difficulty than the first; thus the black oxide of manganese easily gives up one proportion of oxygen by a red heat, but no degree of heat can expel the whole. In the same manner, the last portions of carbonic acid are expelled from carbonate of lime, with great difficulty —the first with ease.

To effect complete decompositions, also, it is sometimes necessary to employ large quantities of the decomposing substances, as in precipitating a metallic oxide from its union with an acid, and in decomposing various salts by acids, as the nitrate of potash by sulphuric acid.

Partial decompositions are produced also by the exertion of a weaker affinity, if it is aided by a larger quantity of matter, as in the case of muriate of soda and oxide of lead. From these, and other similar facts, the distinguished chemist Berthollet drew the conclusion "that affinity is modified by quantity of matter, or that the chemical action of a body is exerted in the ratio of its affinity and quantity of matter, and he endeavored to establish it as a law, applying to all cases of chemical combination."—(*Murray.*) He supposed also that "when two substances are in competition to combine with a third, each of them obtains a degree of saturation proportionate to its affinity multiplied by its quantity; a product which he denominates *mass.*"—(*Ure.*)

Berthollet supposed that the tables of affinity expressed merely the actual order of decomposition, as influenced, not only by affinity, but by quantity of matter, and many other circumstances, and that there was no such thing as a settled force of affinity, between different substances. Berthollet contended also, that in proportion as it requires more of a particular base to saturate a given acid, the less is the affinity between that acid and the base.

But we will not occupy time with views, which however ingenious and ably supported, appear not to be universally tenable. Many of the facts adduced in support of them, can be explained in other ways, and the well established doctrine of definite proportions could not be true, were there no exact force of affinity, independent of quantity of matter. Still, quantity of matter does undoubtedly operate in many cases, to a certain extent, and "although incompetent to counteract direct and strong affinities, or to affect the combination of bodies which are disposed to unite in definite proportions, its influence may be clearly traced in a number of instances, where it modifies weaker attractions, and perhaps decides the result, when opposite affinities are nearly balanced."*—(*Murray.*)

---

* See Prof. E. Mitchell's paper on the effect of quantity.—*Am. Jour. Vol. XVI,* p. 234.

2. *Cohesion.*—It has been already stated that this power is the immediate antagonist of chemical action, which rarely takes place till it is overcome. Hence the great advantage of solution and fusion, which are the most common means of inducing chemical action. In a few cases, the energy of attraction is so great as to overcome the cohesion of two solids, and cause them to unite, and to become fluid in the act of combining. Muriate of lime and snow, and caustic fixed alkalies and snow are examples. Even fluids may have their energy exalted by increased temperature, as is the case with nitric acid and alcohol or oils, and with sulphuric acid and water :* if these fluids are hot it is scarcely safe to mingle them in any considerable quantity. Heat always promotes chemical combination, when cohesion is an obstacle, and often, it is sufficient that one of the substances should be fluid. Mechanical division favors chemical action, principally by increasing the surface. Cohesion resulting from chemical action often modifies the results of experiments. A mixture of sulphuric and muriatic acids, with a solution of baryta, will result in the formation of sulphate of barytes; in part, no doubt, on account of its insolubility, but the effect must depend also upon a superior affinity.

3. *Insolubility.*—This depends upon cohesion, and has reference to the solvent power of the liquid in which the cohesive power is exerted. It removes the body, newly formed from the sphere of action, and thus leaves the remaining principles free to act upon each other.

4. *Gravity.*—So far as there is a great difference in the gravity of bodies that are mixed, it goes to retard chemical action. Thus, salt at the bottom of water dissolves much more slowly and unequally than if it is agitated; and if allowed to remain quiet, the solution will be most dense at bottom, and the least so at top. If metals of widely different specific gravity are melted together to form an alloy, a larger proportion of the heaviest metal will be found at the bottom, and agitation is necessary, in order to bring the particles into proximity, so that the union may be effected.

5. *Elasticity.*—This power, under different circumstances, both opposes and favors chemical action. In general, gases are not prone to combine, because their ponderable particles are too far removed from each other by the caloric, with which they are united. Thus oxygen and hydrogen gases may be retained in mixture, without combining: till flame causes them to unite explosively. Ammonia and the acid gases unite readily, and even precipitate solid matter, and one gas,

---

* Dr. Turner remarks, (Chem. 2d Ed. p. 137,) that "fluids commonly act upon each other as energetically at low temperatures, or at a temperature just sufficient to cause perfect liquefaction, as when their cohesive power is still farther diminished by caloric." The familiar instances mentioned in the text show that this remark needs to be qualified.

in the nascent state, will unite with another already in the elastic form; thus hydrogen unites with nitrogen, to form ammonia, and both these gases, evolved from putrefaction, combine in their nascent state, and form the same body.

Mechanical force favors the combination of gases with each other, and with fluids; oxygen and hydrogen can be made to combine by sudden and violent pressure;* and pressure, cold and agitation are the usual means of impregnating fluids with gases, as in the case of soda water.

Elasticity favors decomposition. When one constituent of a body is prone to assume the ærial state, in general that body is more easily decomposed, both by heat and by affinity, than if both ingredients were fixed. This is the case with the carbonates, and with water contained in crystals, and other combinations; and even potassium is driven off by its superior volatility, at an intense heat, when the alkali containing it is brought into contact with highly ignited iron. Many instances in illustration of these views will occur as we proceed.

6. *Efflorescence.*—This is a circumstance of no great importance, but it sometimes favors chemical action, by withdrawing a salt that has been formed, from the field of action, and in this manner leaving the remaining ingredients free to act again. Thus in the country around the natron lakes in Egypt, muriate of soda and carbonate of lime mutually decompose each other, and the carbonate of soda crawls up in crystals upon the grass and other bodies accidentally present. A similar effect I have often observed upon common plaster, made with sea sand containing muriate of soda, which undergoes decomposition, with the carbonate of lime, and forms by efflorescence a pluverulent carbonate of soda appearing like a fine snow upon the walls.

7. *Temperature.*—The relation of bodies to heat is of the utmost importance with respect to chemical action; but the principal facts have been already adverted to, under other heads, and will be constantly illustrated in our whole progress through the science of chemistry. In general, however, it may be said that there are few chemical events which are not either brought on by change of temperature, or which do not induce a change in that particular.

8. *Pressure*, is an important auxiliary to chemical action. It often determines its commencement, as in the fulminating powders, and the mixtures of the chlorate of potassa with combustibles. It appears to operate both by causing approximation of particles, and by inducing augmentation of temperature. Its agency on elastic fluids in relation to each other, and in relation to them and gross fluids, and even to solids, is not less important. But most of the leading facts have been mentioned already, or will be mentioned hereafter.

---

* Probably in consequence of the heat evolved.

9. *Galvanic Electricity*, is one of the most important of these causes. Its general powers have been already sketched, and it will be more fully developed in the sequel.

(HH.) LIMITATIONS OF COMBINATION.

1. *Unlimited on both sides.*—Water and alcohol, and water and the strong acids are examples; the smallest quantity of the one may be combined with the largest of the other, and the reverse; a drop of water with an ocean of alcohol; a drop of alcohol with an ocean of water.

2. *Limited on one side.*—In the case of water and saline substances, the smallest portion of salt may combine with the largest quantity of water, but if we continue to add the salt, the water becomes saturated, and any additional quantity will remain on the bottom undissolved. Alcohol with camphor and resins, is governed by a similar law.

3. *Limited on both sides* to one proportion. Hydrogen gas 3 volumes, and nitrogen gas 1, unite to form ammonia. Chlorine gas and hydrogen gas, in equal volumes, form muriatic acid.

4. *Limited to one of several proportions.*—Nitrogen and oxygen unite in the several proportions to form nitrous oxide, nitric oxide, and the nitrous and nitric acids.

Hydrogen 2 volumes + oxygen 1, form water.
Hydrogen 2 " " 2, form deutoxide of hydrogen.

(I I.) THE PROPORTIONS IN WHICH BODIES COMBINE ARE GOVERNED BY FIXED LAWS.

Before proceeding to illustrate this proposition, we must observe, that there is a vast variety in different cases, in the force of chemical attraction. Sulphate of barytes is hardly decomposed by any single agent, and other bodies of whose compound character we cannot doubt, as fluoric acid, have not been decomposed at all; because the force of affinity is so strong between their principles, that nothing has been able hitherto to overcome it. But in other cases, the affinity is so slight that it is subverted by small variations of temperature, or by very feeble attractions; as when alcohol is separated from water by distillation, or salts crystallized by the simple cooling of their saturated solutions; so, alcohol holding camphor in solution, gives it up readily when water is introduced, which attracts the alcohol.

(*kk.*) *Properties of simple solutions, and of other feeble combinations.*—The properties are, not at all, or but little changed, and often in no other way, than to produce modified qualities, depending on those of the parent substances, and on their proportions. Solutions of gum, sugar, salts, and acids in water; and of resins, essential oils and camphor in alcohol are familiar examples. Such cases resemble mixtures, in as much as there is little or no change in the properties of the principles; and we readily perceive, either by our senses or by the application of easy tests, the predominance of the one or of the other, or their equality. On the other hand, they resemble chemical combinations, because the principles cannot be separated by any mechanical means; neither repose, agitation or filtration, has any effect; and decomposition, when one ingredient is sensibly more volatile than the other, is effected by evaporation or distillation, or in other cases, by the intervention of an affinity; or by cold.

(*Ll.*) *This class of compounds appears to be intermediate between a mechanical and chemical condition.*—We seem to need a division of this kind; it would free us from embarrassment, with respect to the universality of definite proportions, and it is more reasonable to admit such a division than to suppose the existence of innumerable mixtures of different combinations, in definite proportions, of such things as sugar and water, alcohol and water, &c.

As no single word expresses their peculiarities, and for want of a better designation, they may be called chemico-mechanical, or mechanico-chemical compounds.

There is great variety among chemical compounds, in the degree in which their properties are changed and new properties produced. Thus, it is observed, that although there is in general no resemblance between water and its constituent principles, oxygen and hydrogen, it retains the high refractive power which is characteristic of hydrogen; and again the ammoniacal salts formed between ammonia and the acid gases, retain a great volatility, although in other respects widely different from their principles; the muriate and the carbonate of ammonia are striking examples. There is however no difficulty in assigning such compounds to the class that is strictly chemical, and they would certainly not belong to that which is chemico-mechanical. This last division is very distinctly separated from mere mechanical mixtures; silicious sand and lead shot, marble powder and powder of clay, among solids; and oil and water, and water and mercury, among fluids, would never be confounded with the class of chemico-mechanical compounds, which we would separate from those that are truly chemical. Nor is there any difficulty with respect to cases of mere superficial adhesion, as between tallow and iron filings, atmospheric dust and oils, pollen and varnishes and paints, &c. The union is mechanical, and is to be referred clearly to cohesion or aggregation.

Admitting the distinction that has now been attempted to be established, there can be no hesitation in adopting the doctrine of

DEFINITE PROPORTIONS.

(MM.) IN ALL ENERGETIC COMBINATIONS, THE PROPORTIONS OF THE CONSTITUENT PRINCIPLES, WHETHER THEY ARE SIMPLE OR COMPOUND, ARE DEFINITE.

(*nn.*) *Instances of definite compounds are innumerable.*—Thus, sulphate of baryta, whether formed by art, or existing for ages, as a natural production, is composed of baryta 40 parts, and sulphuric acid 78; and they cannot be made to combine in any other proportion; if the acid and a solution of the earth are mingled in any different proportions, the ingredient that is in excess will be left untouched.

Baryta itself is composed of the metal barium 70, and oxygen 8=78, and sulphuric acid of sulphur 16, and oxygen 24=40. Nitrate of potassa (saltpetre) is composed of nitric acid 54, and potassa 48=102, and nitric acid is composed of nitrogen 14, and oxygen 40=54, and potassa of potassium 40, and oxygen 8=48.

(*oo.*) *The combining power of all bodies can be expressed by numbers.**—This remarkable fact can be rendered intelligible by the following instance. In the composition of water, the oxygen always sustains to the hydrogen the proportion of 8, by weight, the hydrogen being 1, and when they are in the gaseous state, those proportions will be found to correspond to 2 volumes of hydrogen and 1 of oxygen; their specific gravities being in the proportion of 1 hydrogen to 16 oxygen, it of course requires a double volume of hydrogen to sustain the proportion by weight of 1 to 8.

(*pp.*) *In order that numbers may express correctly the combining power of bodies, they must refer to a common unit.*—Oxygen and hydrogen are the bodies which have been selected for this purpose: different philosophers have adopted, some the one and some the other; but there is in my view a decided advantage in adopting hydrogen, and in expressing its lowest combining proportion by 1. We thus avoid fractional expressions, for it would appear from the researches of Prout and others, that the combining powers of all bodies may be expressed by numbers which are multiples or reduplications of that which expresses the combining power of hydrogen. We go upon the supposition that hydrogen enters into combination with oxygen to form water, in a smaller proportion than it enters into the constitution of any other body; and also that there is no body whatever that enters into combination in so small a proportion as hydrogen. We have, it is true, only negative evidence in support of either of these propositions, although the presumption that they are true amounts almost to certainty. But should it be hereafter discovered that hydrogen enters into some combination in a less proportion than it exists in water; or that some other element enters into combination in a proportion still smaller than any known proportion of hydrogen; even then the numerical *relations* would not be in the least disturbed, only the numbers expressing them would be doubled, tripled or quadrupled, &c. according as the unit was placed lower in the scale. For instance, should we find a compound in which hydrogen exists in half the weight that it does in water; then the composition of water, (the lowest known proportion of hydrogen being still unity,) would be expressed by 1 of hydrogen and 16 of oxygen, and in the same manner all other numbers expressing combining ratios would be doubled.

---

* This most remarkable fact evidently depends upon the original constitution of things; and is as truly a law of the physical universe, as that its gravitation is directly as the quantity of matter, and inversely as the square of the distance.

(*qq.*) *The foundation of the doctrine of definite proportions is therefore laid in the constitution of things, and the facts discovered by analysis, have been confirmed by calculation.*—If discovery had proceeded no farther, the knowledge obtained would have been both highly valuable and interesting, but it was reserved for Mr. Dalton,[*] to discover the next law which, although built upon that which has been already announced, is perhaps still more extraordinary.

(RR.) **IF TWO SUBSTANCES UNITE, IN SEVERAL DIFFERENT PROPORTIONS, THE LOWEST COMPOUND WILL CONTAIN ONE, OR BOTH PRINCIPLES IN THEIR SMALLEST COMBINING PROPORTION; AND IN THE HIGHER, THE PROPORTIONS WILL BE SUCH AS ARE PRODUCED BY MULTIPLYING THE LOWEST BY SOME WHOLE NUMBER.**

In a word, the higher proportions are multiples of the lowest, by a whole number, or, the difference will be expressed by a whole number, and the lowest is generally a divisor of the higher without a remainder.

In compounds of A+B, supposing the first compound to be of the smallest proportions of each, and that A remains constant, then the other compounds will be A+2B, or +3B, or +4B.

"The following table[†] will illustrate the subject.

Water is composed of	hydrogen	1.	oxygen	8
Deutoxide of hydrogen	do.	1,	do.	16
Carbonic oxide,	carbon	6,	do.	8
Carbonic acid,	do.	6,	do.	16
Nitrous oxide,	nitrogen	14,	do.	8
Nitric oxide,	do.	14,	do.	16
Hyponitrous acid,	do.	14,	do.	24
Nitrous acid,	do.	14,	do.	32
Nitric acid,	do.	14,	do.	40"

In the two first lines, the proportion of hydrogen is the same, while in the second that of the oxygen is doubled; in the third and fourth lines, similar relations exist between carbon and oxygen, and in the four last, while the proportion of nitrogen is constant, that of the oxygen is double, triple, quadruple, and quintuple.

---

[*] Of Manchester, England, who is still living.

[†] Turner, 2d ed. p. 151.

This is the law that has usually been called the law of multiples, or of multiple proportions, and there can be no doubt that it is true to a very great extent, although, at present, we are prevented, by a very few apparent exceptions, from regarding it as quite universal.

Thus, hydrogen being 1, lead is represented by the number 104, and manganese by 28, and each of these metals has three oxides, which are found to contain respectively, 8, 12, and 16 of oxygen, which is in the proportion of 1 1.5 and 2; so iron, whose equivalent is 28 has, in its two oxides, 8 and 12 of oxygen, which also are in the proportion of 1, and 1.5. This does not correspond with the doctrine of multiple proportions; the difficulty would, however, be removed, should an oxide of each of these metals be discovered, with 4 of oxygen, instead of 8; or possibly there may have been a mixture of oxides, as of the protoxide and peroxide of lead, thus giving origin to an apparent deutoxide, which may not really exist.* Should these cases, however, prove in the end to be exceptions, they will not invalidate the truth of the general doctrine.

(*ss.*) *The number representing any compound body is composed of the sum of the numbers representing its parts.*—Thus in sulphate of potash, whose equivalent is 88, sulphur 16, +3 proportions of oxygen 24=40, and potassa is composed of potassium 40, and 1 proportion of oxygen, 8=48, which +40=88; this will hold true of the most complicated as well as of the most simple compounds.

This truth is well illustrated by all the salts.

(*tt.*) "*The respective quantities of any number of alkaline, earthy, and metallic bases required to saturate a given quantity of any acid, are always in the same ratio to each other, to what acid soever they may be applied.*"†—Soda 2 parts, and potassa three parts respectively, these numbers always bearing the same relation to each other, and to some unit, saturate every acid; soda is represented by 32, and potassa by 48, hydrogen being one, and 32 : 48 :: 2 : 3, as above, and these numbers therefore constantly represent the combining power of these two alkalies; but the proportions of the different acids which will combine with these, and with other bases, will of course vary.

(*uu.*) "*The respective quantities of any number of acids required to saturate a given quantity of any base, are always in the same ratio to each other, to what base soever they may be applied.*"†—This is only the converse of the other proposition, the relative proportions of any two acids that saturate a given base, will saturate any other base, and are therefore called chemical equivalents, and the same is true of the bases, in relation to the acids.

---

* Turner. † Prof. Olmsted, in Am. Jour. Vol. XII, p. 1.

Wenzel, a German chemist, proved, in a work published in 1777, that two neutral salts that decompose each other, still preserve their neutrality; neither acid nor base being in excess,* and Richter, of Berlin, illustrated this truth more fully in 1792. This could not have been true, had not the relations of acids and bases been constant, as stated in the two last propositions. Thus, in sulphate of potassa, the acid is in the proportion 40, and the alkali 48=88, and in nitrate of baryta the acid is 54, and the earth 78=132. Now when these salts are, by double decomposition, converted into sulphate of baryta, and nitrate of potassa, the 54 parts of nitric acid in the nitrate of baryta will saturate and be saturated by the 48 parts of potassa in the sulphate of potassa, making 102 of the new salt, the nitrate of potassa, and the 40 of sulphuric acid in the sulphate of potassa, will saturate and be saturated by the 78 of baryta, in the nitrate of baryta, making 118 of the sulphate of baryta. The facts may be concisely expressed thus.

Before decomposition.

Sulphuric acid 40 + potassa 48 = 88 sulphate of potassa.
Nitric acid 54 + baryta 78 = 132 nitrate of baryta.
220

After decomposition.

Sulphuric acid 40 + baryta 78 = 118 sulphate of baryta.
Nitric acid 54 + potassa 48 = 102 nitrate of potassa.
220

The sum of the constituents being the same after decomposition as before, it is obvious there can be no excess of either.

Thus then, hydrogen being unity, we are to infer that 40, or a multiple of it by a whole number, will always express the combining power of sulphuric acid, and so of other principles.

(VV.) CHEMICAL EQUIVALENTS ARE THOSE DEFINITE QUANTITIES OF PARTICULAR SUBSTANCES THAT SATURATE DEFINITE QUANTITIES OF OTHER SUBSTANCES.

This is only expressing in the form of a proposition, what has been already stated; namely, that a unit being chosen, it becomes possible to express the combining power of all bodies, both simple and compound, by numbers. Thus, if the combining power of hydrogen be

---

[*] For an interesting account of the progress of the doctrine of definite proportions see the introduction to Dr. Thomson's First Principles of Chemistry.

expressed by 1, that of oxygen will be 8, that of carbon 6, that of sulphur 16. If hydrogen and oxygen unite in one proportion of each, the compound will be expressed by 9,—this is the number representing water, and every combination of water will be expressed by 9, or 18, or 27, or 36, and so on, even to ten proportions, which would be expressed by 90.

(*two.*) *The combining weight or power of a body being once ascertained, it will always remain the same; or it will sustain the same ratio in every combination.*—If the combination takes place in different proportions with a given body, the number expressing the lowest proportion will be constant, and the higher proportions will be multiples of it, by a whole number. Thus, hydrogen being unity, oxygen will always enter into combination in the proportion 8, 16, 24, 32, &c.; carbon in the proportions 6, 12, 18, 24, &c. The combining weights or powers of bodies, both simple and compound, may therefore be permanently registered in a table of chemical equivalents. Such a table is now attached to every treatise on chemistry, and is constantly referred to in practical operations, both of science and art. It is an important auxiliary, for we discover by inspection what quantities of particular bodies saturate, or are equivalent to each other. In the present work the chemical equivalents, as far as they are ascertained, will be found connected with each body, in its proper place, and they will be collected in a table at the end.*

Dr. Wollaston's Scale of chemical equivalents.†—This is a table of combining or proportional weights, embracing those bodies that are most frequently used in practical chemistry. It differs from other tables only in this, that while the names of the substances are stationary, those of the numbers are placed on a sliding rule, divided logometrically, according to the principle of that of Gunter. The advantage of the instrument is, then, that it not only presents a table of chemical equivalents, but by moving the sliding rule in a proper manner, many proportions can be mechanically worked, without the trouble of calculation. Thus, it has been already stated, that sulphate of potassa is composed of acid 40+ potassa 48, and therefore 88 is the number expressing the composition of the salt; hydrogen being the unit, all this will be seen, by placing the scale in such a position that 8 is opposite to oxygen; but if we wish to know what would be the proportion of the acid and alkali, in 100 parts of sulphate of potassa, we have only to bring the scale into such a position, that 100 will be opposite to sulphate of potassa, when we shall read opposite to potassa 54.5, and to sulphuric acid 45.5, which is the composition in 100 parts.

---

* A very valuable table is annexed to Dr. Thomson's First Principles of Chemistry, and Mr. Brande has published, in a separate work, the equivalents of all bodies as far as they are known.

† For a description of this beautiful instrument, see the Phil. Tr. for 1814.

Dr. Wollaston called oxygen 10. When this number was opposite to oxygen, the other numbers, therefore, estimated by that scale, represented "the combining weights of the bodies opposite to which they may be found." "By mere inspection of this scale, we discover the quantity of one body which enters into combination with another, the proportions of the elements of compounds, and the quantities of these which enter into the composition of any particular weight of a compound; the quantity of any substance required to decompose a compound, by combining with either of its ingredients, and the quantity of the products that will be formed." The progress of analysis has shewn that the numbers attached to Dr. Wollaston's scale are, in many instances, incorrect, but these errors have been rectified in more recent editions of the scale,* in which, also, the more convenient unit of hydrogen has been adopted.

It is now ascertained that the foundations of chemical combination are laid in mathematical relations, and the proportions of bodies have therefore become subjects of mathematical calculation, as well as of analytical experiment. The mathematical relations are proved by analysis, to be true, and analysis is, in its turn, guided and corrected by calculation. We may be assured that an analysis is wrong if it does not correspond with numerical ratios, and we may predict that the result will be expressed by one of a certain set of numbers, related to each other by the same ratio, provided we are correctly acquainted with any one combination of the same principles; the new compound of these principles will bear a relation to them which may be expressed by whole numbers, although we cannot be certain whether it will be double, triple, quadruple; or a half, or a third, or a fourth, &c. of the one known; it will be certain, or in the highest degree probable, that it will not be expressed by any intermediate number.

This beautiful discovery, as its foundations are laid in the exact relations of quantity, places chemistry upon a mathematical basis.

Mr. Higgins gave the first hint of this subject in 1788, in his view of the phlogistic and anti-phlogistic theory, but Mr. Dalton first clearly explained the doctrine.

COMBINATION BY VOLUMES.

(XX.) GASEOUS BODIES UNITE BY VOLUME, IN THE SIMPLE RATIO OF 1 TO 1, 1 TO 2, 1 TO 3, 1 TO 4, &c.—This law was established by Gay Lussac, and Humboldt,* and the first fact of the kind observed, was in the case of the elements of water, two volumes of hydrogen combining with one volume of oxygen.

---

* As by Mr. Reid, in Britain, and by Messrs. Henry and Beck, of the Rensselaer School at Troy, N. Y., and by Dr. Barrat, at Middletown, Con.

The following tables† exhibit a number of facts of this class.

Volumes.				Volumes.		
100	muriatic acid gas	combine	with	100	ammoniacal	gas.
100	carbonic acid gas,	"	"	100	do.	do.
100	do. do.	"	"	200	do.	do.
100	nitrogen gas,	"	"	50	oxygen	gas.
100	do.	"	"	100	do.	
100	do.	"	"	150	do.	
100	do.	"	"	200	do.	
100	do.	"	"	250	do.	
100	Chlorine gas,	"	"	100	hydrogen	gas.
100	nitrogen gas,	"	"	300	do.	
100	oxygen gas,	"	"	200	do.	

This table needs no comment; supposing it to be accurate, of which there can be no reasonable doubt, it fully supports the proposition stated above.

(*yy.*) *Bodies in the state of vapor obey the same law.*

"100 vols. hydrogen + 100 vols. vapor of sulphur = sulph'd hydrogen.
100 " oxygen + 100 " " = sulphurous acid.
100 " " + 100 " iodine = hydriodic acid."‡

This view is carried so far as even to embrace solids, which, perhaps, have never been in the aëriform condition, except in a state of combination; it is supposed that in that state, they would obey the same rule. In the compound gases just mentioned, it is obvious that the specific gravity and proportion of the oxygen in sulphurous acid, and of the hydrogen in sulphuretted hydrogen being known, the balance of the weight of the gas under a given volume, must represent the sulphur in the state of vapor; and the same remark will apply to the hydriodic acid; we may include the carburetted hydrogen gases in the same view, for the specific gravity of the hydrogen which they contain, and its proportion being known, it is obvious that the remainder of the weight in a given volume must be carbon in a state of vapor.

(*zz.*) *When gases suffer condensation, in consequence of combining, it is always in a simple ratio to the volume of one of them.*—Ammonia is composed of 3 vols. of hydrogen + 1 vol. of nitrogen, contracted into 2 vols. and in the formation of nitrous oxide gas there is a contraction to two thirds. In the formation of sulphuretted hydrogen, and sulphurous acid, there is also a contraction to one half; and the same fact is seen in many other cases.

---

* Memoires d'Arcuell. † Murray, 6th Ed. Vol. 1, p. 67. ‡ Turner.

(*aaa.*) *By knowing the specific gravity of the gases composing a compound gas, and the degree of condensation which they undergo, the specific gravity of the compound gas may be calculated.*—Dr. Turner has given the following instances among others. Ammonia, as just observed, contains 3 vols. hydrogen, and 1 of nitrogen, condensed into 2 vols. The sp. gr. of hydrogen is 0.0694, air being 1, and that of nitrogen is 0.9722—therefore the latter number $+0.0694\times3=\frac{1.1804}{4}=0.2951$, the sp. gr. which ammoniacal gas would have, were there no contraction of the gases; but as they contract one half, the sp. gr. will be double of that, or 0.5902, which is its weight, as ascertained by experiment by Sir H. Davy. Nitric oxide gas, being composed of 100 vols. of oxygen, and 100 of nitrogen, united without contraction, must form 200 volumes of the compound, and of course the sp. gr. must be the mean of its components, or $\frac{1.1111+0.9722}{2}=1.0416$, which accords with the average results of the best experiments.

(*bbb.*) *The combinations by volume coincide accurately with the law of multiple proportions, for it is obvious that double, triple, &c. of the volume of a gas must also be double, triple, &c. of the weight.*—There is also an additional coincidence, that is not possessed by the compounds that are not aëriform. Although in them there is an arithmetical relation between the weights of the different proportions of the same principle, there is no such correspondence between the different principles of the same compound. Thus, between the 14 parts by weight, of nitrogen, and the 8 of oxygen, contained in nitrous oxide; and the 14 and 16 parts of the same principles, in nitric oxide; and the 6 of carbon, and 8 of oxygen, in carbonic oxide; and the 6 and 16 of the same principles in carbonic acid, there is no multiple relation.

(*ccc.*) *In combinations of aëriform bodies, there is a multiple relation, not only between the different proportions of the same principle, but of the different principles, that are united in the same compound.*—The table on page 167 proves this proposition to be true.

(*ddd.*) *In general, a volume of a gas represents a combining proportion.*—Oxygen is the only exception; in that gas, half a volume represents a combining proportion. This arises from the fact that in the lowest combination of oxygen known, it unites with two volumes of hydrogen, which are supposed to contain only one combining proportion, and therefore the combining proportion of oxygen is considered as contained in half a volume of that gas.

(*eee.*) *Although, in general, there is no arithmetical ratio between the combining proportions of different bodies, hydrogen forms an exception.*—According to Dr. Prout,* and Dr. Thomson,† "in every one of the compounds of hydrogen, the proportion of the body united with it, is an exact multiple, by a whole number, of its own weight."‡ Thus, in water, (protoxide of hydrogen,) the oxygen is just 8 times the weight of the hydrogen, while in the deutoxide, it is 16 times; and in sulphuretted hydrogen, the sulphur is just 16 times the weight of the hydrogen.

(*fff.*) *Berzelius§ has discovered that oxygen contained in different proximate principles of the same compound, exists in a multiple ratio, or in equality.*—Thus, hydrate of potassa is composed of potassa 48, and of water 9, and there is 8 of oxygen in each of them. This law holds in earthy minerals, containing several oxides, and in the salts.

Carbonate of potassa consists of carbonic acid 22, containing oxygen 16, and of potassa 48, containing oxygen 8.

Where water of crystallization is present, there is a similar relation.—Crystallized sulphate of soda contains sulphuric acid 40, in which the oxygen is 24; soda 32, with oxygen 8, and water 90, with oxygen 80; and these numbers, 8, 24, and 80, consist of one, three, and ten proportions of oxygen.

Compound salts obey the same law.—In tartrate of potassa and soda, the oxygen in the acid, and in the two alkalies is the same.

(*ggg.*) "In each series of salts the same relation always exists between the oxygen of the acid and of the base." In the neutral sulphates, the ratio is as 1 to 3—one in the alkali, and three in the acid. In the carbonates the acid is double, and in the bi-carbonates, quadruple the oxygen of the base.

The illustrious discoverer of these most remarkable laws, says that in the course of several years that have passed since he first observed them, he has not detected any exception, and he therefore relies upon them implicitly, and is in the habit of calculating the composition of bodies upon this principle.||

---

* Annals of Philosophy, Old Series, Vol. VI, p. 321.

† First Principles.

‡ This is denied by Berzelius, who asserts that it is inconsistent with the results of his analysis.

§ This account of the discoveries of Berzelius, is abridged from Dr. Turner's Chemistry, 2d Ed.

|| For an able view of this subject, see Dr. Turner's Chemistry, 2d Ed. p. 177.—He gives the following generalization. Most of the neutral sulphates, all the alkaline and earthy, and several metallic sulphates of common metals, as iron, zinc, and lead, consist of 1 proportion of acid, and 1 of base; the acid contains 1 proportion of sulphur, 16, and 3 of oxygen, 24, and every protoxide consists of metal 1 proportion, and oxygen 1=8. It will be seen by comparing the numbers that

1. "The oxygen of the acid is a multiple of that of the base."
2. "The acid contains three times as much oxygen as the base."

THEORY OF ATOMS.

For a complete view of this curious and interesting speculation, recourse must be had to the writings of Higgins, Dalton, Berzelius, Thomson and others.*

In the sketch that has been given of definite proportions, I have intentionally avoided the use of the word atom, because it may be misunderstood, and may lead beginners to confound facts with hypothesis. The doctrine of definite and multiple proportions is established on the basis of experiment, and is fully confirmed both by analysis and calculation.

The expressions, *combining weight*, *combining quantity*, *or combining proportion*, *and chemical equivalent*, all mean the same thing; and it may be added, that *atom*, *and atomic constitution and atomic weight*, are used by most writers in the same sense. The atomic hypothesis, first suggested by Mr. Higgins, (1789,) was so fully detailed and illustrated by Mr. Dalton, in his Chemical Philosophy, that the theory is usually considered as his. It is ingenious and beautiful, and there can be no reasonable doubt that matter has an atomic constitution; but, that it is such as the atomic theory now in discussion supposes, although highly probable, cannot be demonstrated; and it is therefore important for the student to be able to distinguish it, or any other atomic theory that may be proposed, from the luminous and demonstrated verity of definite and multiple proportions.

(*hhh.*) If we assume that bodies, in the combination in which they exist in the smallest proportions, unite atom and atom, then their relative weights in those cases, will represent those of their atoms. This assumption is the foundation of the atomic theory.

(*iii.*) There being no combination in which hydrogen is known to exist in smaller proportion than in water, and the specific gravity of hydrogen to oxygen being as 1:16, if these elements unite atom to atom, and a volume of each represents an atom, then the relative

---

3. "The sulphur of the acid is just double the oxygen of the base."
4. The acid itself is just five times as much as the oxygen of the base.

Metallic sulphurets often contain one proportion of each element, and when converted into a salt, the sulphuric acid and the protoxide will be exactly in the proportion for forming a neutral sulphate of a protoxide.

In the carbonates, the oxygen of the acid is generally double that of the base, and a similar mode of reasoning is applicable to the various genera of salts; but no constant ratio exists between the quantity of oxide and that of the acid, or of the oxygen in the acid, because the combining weights of the metals themselves are different. All these facts are arranged naturally under Mr. Dalton's principle of multiple proportions.

An attempt has been made to extend the same views to the constitution of minerals.—See Ann. of Philosophy, N. S. Vol. IX, Mr. Children.

* See Henry, 10th London Ed. Vol. I, p. 42. Thomson's First Principles of Chemistry, and Turner and Murray.

weights of the atoms will be as those numbers; but as it requires two volumes of hydrogen gas to saturate one volume of oxygen gas, it follows that if the two volumes of hydrogen be expressed by 1, viz. be regarded as one atom, half a volume of oxygen must be the equivalent of the hydrogen, and will be expressed by 8.*

(*jjj.*) Either of these elements† being taken as unity, then the weights of the atoms of other bodies may also be expressed by numbers, having an arithmetical relation to those attached to these two elements, and thus we may construct a table of atomic weights.

(*kkk.*) If we could be certain that we actually know the lowest proportions in which bodies combine, and that in them the constituents are united atom and atom, then their definite proportions and their atomic weights would correspond; or at least they would be multiples and divisors, generally, of each other, and always by whole numbers.

(*lll.*) But we can never be certain, that we either know the smallest combining quantities of bodies, or that those quantities, if known, are relatively in the proportion of atom and atom, or of one atom of one and of two of another, or vice versa, or of some other proportion; we cannot therefore be certain that our atomic hypothesis is true.

(*mmm.*) This however does not affect the truth of the theory of multiple proportions; that great discovery is independent of hypothesis, because the exactness and arithmetical relation of the proportions is a matter of fact, and will still be true, whether the lowest combination is formed by atom and atom of different bodies, or by one atom of one and two of another, or the reverse; or by any other assortment that may be imagined.

(*nnn.*) The atomic theory is an elegant hypothesis, framed to account for definite and multiple proportions, and may be either true or false without affecting that sublime truth, which deserves to be inscribed on the same tablet with the laws of gravitation and projection.

(*ooo.*) Still the hypothesis is highly probable, and the probability of its truth is much increased by its surprising coincidence with facts.

(*ppp.*) No student in chemistry, should however, imagine that the doctrine of definite and multiple proportions must stand or fall with the atomic theory. The latter may be discarded, without in the least affecting the former; but the truth of the former is indispensable to the existence of the latter.

I shall, as much as possible, avoid the use of the word atom, since we have no positive knowledge of the nature, forms, number and weight of the atoms of any thing; as the word is short, it may however be convenient to use it occasionally, but it will be understood by the reader, that nothing more is intended by it than combining weight, combining proportion, or chemical equivalent.*

---

* See Mr. Finch's paper on the atomic theory, Am. Jour. Vol. XIV, p. 24.

† Other elements might have been used for this purpose; but none are equally convenient with oxygen and hydrogen.

It will doubtless be thought by some, that the atomic theory should be presented more in detail. There can be no objection to its being studied fully by those who are well versed in chemistry, but the learners of elements, for whom chiefly this work is intended, will, if they have mastered the doctrine of definite and multiple proportions, be able to go forward in their studies without the atomic theory, and to understand that theory the better, the farther they proceed in the science. We do not, however, hold it in small consideration, and a sufficient number of opportunities of illustrating its nature, will present themselves in the study of the particular bodies.†

APPENDIX TO ATTRACTION.

Terrestrial and artificial magnetism, has an evident effect on chemical action.—Before leaving the subject of attraction, it ought to be remembered, that magnetism appears to be connected with it. Tincture of purple cabbage placed in a syphon tube, is changed in fifteen minutes to green, by being connected by an iron wire, with the two poles of a magnet, and when the liquor was in two connected tubes, the same thing happened, but it required two days to effect the change.‡

A syphon tube, half an inch wide, and four and five inches long, having mercury poured into the bend, but not sufficient to cut off the communication between the two branches; the tube is then nearly filled with an acid solution of nitrate of silver. The tube being placed in the plane of the magnetic meridian, the precipitation of the arbor dianæ§ is much more rapid than when it is at right angles with it; and it is much more abundant at the north than at the south end, and the crystals are more brilliant and longer, and more perfect.

A bent tube placed across the magnetic meridian, and in which the crystallization has made little progress, exhibits it in increased activity, when two artificial magnets are approached, the north pole of one to one leg, and the south pole of the other to the other leg of the syphon tube. Circles of tallow being formed on glass plates, solution of nitrate of silver was placed within, and a circular piece of zinc in the centre; the precipitation of silver was much more active towards the north, and the oxide of zinc inclined to the south; a strong magnet being brought within two inches of a plate prepared, as before, the precipitation took place in one fourth of the time, that it did on the plates that were beyond its influence.*

---

* Dr. Wollaston, in a paper on the finite extent of the atmosphere, published in the Phil. Transactions for 1822, has rendered it probable that there are atmospherical atoms incapable of farther division. The question as to the indivisibility of atoms, is a physical topic, entirely independent of the mathematical speculation as to the infinite divisibility of matter; a speculation which seems however to have little utility, and some would say, meaning, except with reference to physical elements.

† Thenard has followed this course, Vol. I, Chem. p. 24, Ed. 5. I heard Mr. Dalton explain his own theory in his lecture room at Manchester, and while I was entertained with the arrangement of his atomic symbols, I was forcibly struck with the still greater value of his discovery of multiple proportions.

‡ The spontaneous change is to red and not to green.

§ A fanciful name given to this peculiar crystallization of silver; the disposition of the crystals being in branches, and silver was formerly called Luna or Diana.

* * * * * *

We have now taken a preliminary view, perhaps sufficiently extensive and detailed, of the general doctrines of chemistry. This was indispensable, to enable us to understand the history of particular bodies, which is to follow; and in giving it, I have endeavored, as far as practicable, to avoid anticipation; still it is possible that some passages may be unintelligible to a beginner; as they are, however, not numerous, they may be omitted in the first reading, and being marked in the margin by a pencil, they can be examined again at a more advanced stage of the subject, when the pupil has become more familiar with chemical facts and reasoning.

The preceding account of the general doctrines, although probably sufficient for an introduction, is far from being complete, and additional illustrations will be given, when the proper facts come in our way.

Before proceeding to the history of particular bodies, it will be useful to say something of the rules of philosophising, and of the apparatus and operations.

I. Rules of Philosophising.—Limits of Human Reason.

1. God is the first cause of every thing.

(*a.*) *All our observations, experiments and reasonings, make us acquainted only with second causes.*

(*b.*) *The proximate cause of an effect, is the one immediately antecedent to the event, or which is principally operative in producing it.*

(*c.*) *To every proximate cause, there may be another proximate cause, and to that cause another; but the series will end at last in the power of the Creator, in immediate agency; and this will still be the fact if we discover ever so many proximate causes, constituting a series or chain apparently endless.*

(*d.*) *When we have classified similar phenomena, and have discovered their modus operandi; we say that we have found out the law that governs them;* but still this harmony of facts and operations, we must trace to the same source.

---

* Am. Jour. Vol. XVI, p. 262, and Ann. de Chim. et de Physique.

(*e.*) *Natural science is to be studied by observing facts, and making experiments, and then drawing conclusions;* this is the inductive or Baconian method of reasoning, and is the foundation of legitimate theory. An experiment is nothing but the exhibition of a fact.

(*f.*) *Hypotheses may be introduced in the absence of true theory founded on induction;* but they can be admitted only provisionally, until something better can be done.*

(*g.*) We will add from Sir Isaac Newton, that, "*we are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances.*"

(*h.*) "*Therefore, to the same natural effects we must, as far as possible, assign the same causes.*"†

(*i.*) *The range of human reason is the whole extent of second causes.*

(*j.*) *The final reason of a particular law is sometimes discovered by us,* and always magnifies the author. The unvarying proportion of oxygen gas in the atmosphere; and the means by which it is probably sustained; the exception in the expansion of water between 32° and 40°; the phosphorescence of marine animals and of fish generally in the ocean, and the circulation of fluids and of aëriform bodies in currents to equalize temperature, are striking instances among multitudes that might be adduced.‡

(*k.*) *The moral effect of physical study upon every mind which has been correctly disciplined, is altogether happy, and augments the vigor of every proper feeling.*—It is not, however, to be denied, that an opposite effect is sometimes produced upon certain minds; but this is the fault of the individual and not of the study. Even moral study sometimes produces the same effect.

(*l.*) *The greatest mental power and the longest life, joined with the greatest industry, can enable man to compass only a small part of universal knowledge.*—Of this, the wisest and the greatest men are the most sensible. Newton was not more distinguished for his vast powers and acquirements, than for his singular modesty. The important suggestions at the end of his optics are in the form of queries. The whole amount of the knowledge of such a man, compared with all that a savage knows, is indeed great; but, compared with universal knowledge, it is an evanescent point.

II. APPARATUS AND OPERATIONS.

Under the head of apparatus, we include all the instruments and utensils employed in chemical experiments.—An experiment being, (as already observed,) only the exhibition of a fact, we want such instruments as will enable us to show facts; they are for utility, and not for mere parade, but in a public establishment, elegance may be in a good degree, combined with utility.

---

* See Lord Bacon's Novum Organum, and De Augment. Scientiarum.

† Principia, Vol. II, Ed. 1803.

‡ See Paley's Natural Theology.

An apparatus is best explained, when it is used; but a few facts may be stated advantageously in this stage of our progress, and the names of some leading instruments and operations may be given.

A considerable number of instruments has already been mentioned, but they have been chiefly those which illustrate general principles, and the greater part have been very intelligible. For private research, and for the instruction of only a few persons at once, a complicated and expensive apparatus is not necessary. Much may be done by cheap and simple means.* Still, it is an error to suppose that refined analysis and difficult researches that demand great precision, can be accomplished without proper instruments, and various and sometimes expensive reagents; nor can full effect be given before a large audience, to the fine experiments with which chemistry abounds, without an apparatus, and materials corresponding in some measure, to the splendor and dignity of the subject.

For a full account of chemical apparatus and operations, the student is referred to Mr. Faraday's excellent work on chemical manipulations, where all the information that can be desired is given.

Apparatus—names of things—heads and hints.—Instruments of chemistry, to be perfect, should be,

(*a.*) Transparent.
(*b.*) Incapable of corrosion.
(*c.*) Incapable of fracture by heat and cold.
(*d.*) Strong to confine elastic vapors.
(*e.*) Not liable to be melted or otherwise injured by heat.

Glass, metal, and earthen ware, collectively possess these properties.

Glass has the two first characters, in a sufficient degree, but not the rest;

Metal, has sufficiently the third and fourth, and

Porcelain or earthen ware, the fifth, provided the heat is carefully managed.

1. *Means of producing heat.*

(*a.*) *Fuel, &c.*—Charcoal, coak, anthracite and other coals; wood, oil, alcohol, ether, hydrogen gas; this gas and oxygen; friction, percussion, fermentation, chemical mixtures.

2. *Instruments in which, and means by which the application is to be made.*

---

* I heard Dr. Priestly say, that his principal instruments were gun barrels, glass tubes, flasks, vials and corks, and it is well known that few men have made more discoveries. Still he was a pioneer; he was always on travels of discovery, and his operations were not in general so remarkable for refinement, as for sagacity and effect.

(*a.*) *Furnaces*, Black's, crucible furnace, table furnaces, Lewis', air furnaces, forge furnace. The general principles of all furnaces are the same. The principal parts are an ash pit and register, a grate, a body, a top, and a chimney. Argand's lamp, spirit lamp, mouth blowpipe, table blowpipe or Artists', Dr. Hare's, compound and hydrostatic, electric and galvanic apparatus, and burning lenses, and mirrors are useful means of producing heat.

3. *Vessels to be used with heat.*

(*a.*) *For fusion.*—Crucibles, Hessian, Wedgewood, Austrian or black lead, charcoal, platinum, gold, silver.

(*b.*) *For mixture.*—All vessels may be employed for these purposes, provided the agents do not act on them. For the solution of salts in the cold, most vessels will answer; with heat, they must bear expansion and contraction. For metallic solutions, they must generally be of glass or earthen; a platinum crucible may however be employed for many metallic solutions.

(*c.*) *For evaporations, distillations, sublimations.—For evaporation.*—Earthen pans, glass dishes, watch glasses, saucers, plates, and porcelain, and metal capsules; those of platinum are very valuable; bottoms of retorts and mattrasses are useful. Almost all vessels answer for crystallizations.

For distillations.—Common still, with its worm and refrigeratory, mattrasses, oil flasks, tubulated and plain retorts and receivers of glass, iron, earthen ware, lead, silver, and gold or platinum; bent glass tubes, closed at one end.

For concentration, decoction, digestion.—Papin's digester, or other strong boiler with tubes and stop cocks; occasionally, almost all vessels are used for boiling.

(*d.*) *For sublimation.*—Most of the vessels last named. Baths of water, sand, ashes, steam, oil, mercury, hot air, alcohol, brine, &c. Alembics of glass, metal, &c.

4. PNEUMATIC APPARATUS AND MISCELLANEOUS ARTICLES.

(*a.*) *Hydro-pneumatic cistern* and air jars.

(*b.*) *Mercurial trough*, usually of stone, furnished with tubes of glass.

(*c.*) Air pump and its appendages. Condensing syringes.

(*d.*) *Gazometers* of different sizes for different purposes. Eudiometers and graduated glass jars, graduated tubes, detonating tubes, Woulfe's apparatus, and Dr. Hare's improvements; do. for impregnating with carbonic acid gas. Stands, supports, &c. of iron and brass; barometer and thermometer; instruments for specific gravity.

5. MECHANICAL OPERATIONS PREPARATORY.

(*a.*) *Trituration.*—Mortars of marble, iron, steel, glass, porcelain, jasper, porphyry, agate, wood, granite.

(*b.*) *Levigation.*—The rubbing stone and muller.

(*c.*) *Pulverization.*—Rasps, files, graters, hammers, anvil.

(*d.*) ***Weighing.***—Scales, coarse and fine, very sensible balances.
(*e.*) *Sifting.*—Seives, of various fineness, with and without covers.
(*f.*) *Decantation.*—Syphons, coffee pots, &c.
(*g.*) *Filtration.*—Unsized paper of various quality, pounded glass, flannel, filtering stones, sand, &c. Filtering funnels and stands.

6. LUTES.

Flour and water, rye paste; sand, flour and clay; fat lute, composed of clay and oil, lime and white of an egg.

7. VESSELS FOR KEEPING PRODUCTS.

Ground glass stopped bottles for deliquescent salts; wide mouthed bottles; common vessels of any description. Tin cases for phosphorus bottles.

Drawers, mineralogical cabinet, bladders and silk bags, for the purpose of administering gases.

8. LABORATORY—*general idea of one.*—Any convenient, light, dry, and well ventilated place for the performance of experiments. Neatness, order, and care of one's person and clothes and premises are indispensable.

Necessity of caution and presence of mind. Unreasonable fears of chemical experiments. Frequent ventilation of a laboratory necessary.

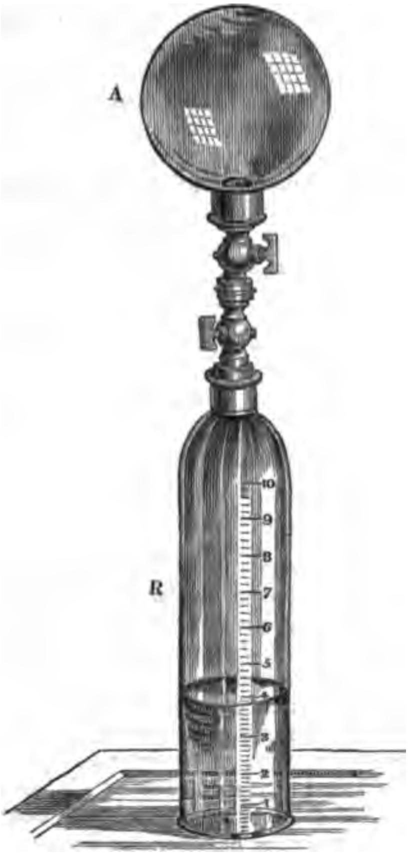
Specific gravity.

The specific gravity of a body is its weight under a given volume. It is often necessary in chemical experiments, to take the specific gravity of bodies. Ample instructions are given on this subject, in every book of Natural Philosophy, and for the present, mention will be made only of its application to gaseous bodies.

It may however be stated, for the sake of those who have not more delicate apparatus, that common money scales are sufficiently exact for most purposes. A fragment of the substance to be weighed, may be suspended by a fine thread or piece of sewing silk, from the point of bearing of one arm of the balance, the thread being long enough to allow the fragment to swing below the scale so as to admit of immersion in pure water; we then proceed as is usual in similar cases. Dr. Hare has several ingenious contrivances and inventions for taking specific gravities, which may be seen in his compendium, and in the American Journal of Science, and if there is room, they may be given in an appendix to this work.

The specific gravity of fluids is easily taken by weighing them in a thin vial with a narrow neck, having a mark upon it so that the same volume may be easily taken; it is most convenient that the vial should hold 1000 grains of distilled water.

Method of ascertaining the specific gravities of the gases.—Dr. Hare.



"Suppose the globe, A, to be removed from the receiver, R, and exhausted during a temporary attachment to an air pump, by means of a screw with which the globe is furnished, and which serves also to fasten it to the receiver, as represented in the figure. Being preserved in this state of exhaustion, by closing the cock, let it be suspended from a scale beam, and accurately counterpoised; air being then admitted, will cause it to preponderate decidedly. If in lieu of admitting air, the globe be restored to the situation in which it appears in this figure, so as to be filled with hydrogen from the receiver, R, and afterwards once more suspended from the beam, instead of preponderating decidedly, as when air was allowed to enter; unless the balance be very delicate, the additional weight, arising from the admission of the hydrogen, will scarcely be perceptible. Supposing, however, that the additional weight thus acquired, were detected; and also the weight gained by the admission of exactly the same bulk of atmospheric air, after a similar exhaustion of the globe, the weights of equal volumes of hydrogen and air, would be represented by the weights thus ascertained. The specific gravity of atmospheric air is the unit, in multiples, or fractions of which, the specific gravities of the gases are expressed. Hence the weight of any given bulk of hydrogen, divided by the weight of an equal bulk of air, gives the specific gravity of hydrogen. By a similar process, the specific gravity of any other gas may be discovered."

"The apparatus for ascertaining specific gravities, above represented, is that which is recommended by Henry. The gas may be more accurately measured, by using one of the volumeters."*

"The weight of any given number of cubic inches of air or gas, as one hundred, for instance, may be known by introducing a certain quantity into the globe, as above described, and noticing the accession of weight: then, as the number of cubic inches introduced, is to the weight gained by its introduction, so is one hundred to the weight of one hundred cubic inches of the fluid."

"The number of cubic inches introduced, may be known by means of the graduation on the receiver, R."

If there be a column of water or mercury standing in the jar, the gas will be less compressed than if there were no such column. Therefore, the density will be *inversely*—the volume *directly* as the height of this column. Hence, to ascertain the volume, say $H : H-h :: v : x$. Here, H is the height of the barometer, h the height of the column,† v the observed volume, and x the volume required.

In weighing the gases in order that the result may be correct, the gas should be pure; it should be dry, or due allowance should be made for watery vapor, and if the experiment is not made when the barometer is at 30 inches, and the thermometer at 60°, the observed volume should be reduced by calculation, to what it would be, at the medium temperature‡ and pressure.

The purity must be secured and ascertained by the modes appropriate to each particular gas.

Moisture must be removed, as far as possible, by exposure to dry muriate of lime, quick lime recently ignited, or fused potash; or other substances that powerfully attract water.§

For temperature; the volume of a gas is as the temperature directly, and as operations on gases are almost always carried on above 32°, we first ascertain the volume that the gas would occupy at that temperature, which is done by multiplying the total volume by‖ 480, and dividing the product by‖ 480, + the number of degrees that the temperature is above 32° Fahr. Then to determine its volume at any other temperature, “ add $\frac{1}{480}$ of the volume at 32°, for each degree that the temperature required, exceeds 32° Fahr. Thus, to find what space 100 cubic inches of gas at 50° would occupy, if raised to 60° $\frac{100\times480}{480\times18}=96.4$, the volume at 32°, and $96.4+\frac{96.4\times28}{480}=102$, the volume at 60°”[*]—*Henry*.

---

* See Dr. Hare's Compendium.

† The column being of mercury, or due allowance made if it is water; a foot of water representing nearly an inch of mercury.

‡ Gloves should be worn while handling the vessels, or they should be lifted by the keys of the stop cocks, that the warmth of the hands may not cause expansion in the gas.

§ For a general formula, see Henry, 6th Ed. Vol. I, p. 25, and Turner, 2d Ed. Vol. I, p. 71.

‖ Because a gas expands $\frac{1}{480}$ part of its volume by every degree of heat.

For pressure; the volume of a gas is inversely as the pressure.—To reduce the volume to what it would be at 30 inches, the mean pressure, “ as the mean height is to the observed height, so is the observed volume to the volume required. Suppose the barometer to stand at 29 inches, and that we wish to ascertain what volume 100 cubic inches of gas would occupy at 30 inches, 30 : 29 : : 100 : 96.66, which last number is the answer required.

For both pressure and temperature.—Suppose the question is, what volume would 100 cubic inches of gas, estimated at 50° of Fahr. and 29 inches of the barometer occupy at 60° and 30 inches. By first correcting the temperature, we find that the 100 cubic inches, would be 102, and then, 30 : 29 : : 102 : 98.6.

The weight of a given volume of gas being known at any temperature, to learn what would be the weight of an equal volume at the mean temperature.—The volume being given, the weight will be directly as the pressure. Correct the bulk to the mean temperature; “ then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required.” 100 cub. in. of gas weighing 50 grains at 50° Fahr. would at 60° occupy 102 cub. in. and 102 : 50 : : 100 : 49.02, which would be the weight of 100 cub. in. at 60°.

From the weight of a given volume of gas at an observed pressure, to ascertain what would be its weight under the mean pressure; say, “ as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight.” 100 cub. in. of gas at 29 of the barometer, weight 50, what would it weigh at 30 inches pressure. 29 : 30 : : 50 : 51.72, the fourth term being the answer.

To combine both the last calculations.—100 cub. in. of gas, at 50° Fahr. and 29 in. pressure, weight 50 grains, what would it weigh at 60° Fahr. and 30 inches pressure; first make the correction for temperature, which gives for the weight under a given volume, 49.02, then, 29 : 30 : : 49.02 : 50.71, which is the answer required.[†]

---

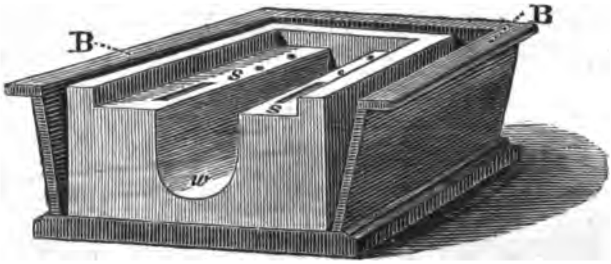
[*] For a general formula, see Turner, 2d Ed. p. 84.

[†] These rules are cited substantially from Henry, 10th Ed. Vol. I, p. 23.

Pneumatic Cisterns.

Dr. Hales, more than a century ago, employed an apparatus upon the principle of the modern pneumatic cistern, which was introduced by Dr. Priestley. This instrument is little else than a vessel sufficiently capacious, filled with water or quicksilver, and furnished with fixed shelves and a sliding shelf. The apparatus for mercury is usually small, on account of the weight and expense of the metal, and ounce measures are used where, in the other apparatus, we employ quarts or gallons of water. In both, for the purpose of expelling the air, the vessels are filled with the fluid, and then, they being inverted with their mouths under it, the gas is introduced from below. The annexed cut represents the mercurial cistern used by Dr. Hare; it is, however, five or six times larger than those generally employed. This kind of cistern is rarely used, except when the gases are rapidly absorbable by water. That in the laboratory of Yale College, is of marble,* and of a similar construction, but holds not over two hundred pounds of mercury, and usually from one hundred and fifty to one hundred and sixty pounds.

Mercurial Cistern for gases.'



" B B, is a wooden box, which encloses the reservoir so as to catch any of the metal which may be spilled over the margin of the cistern. This box is bottomed upon stout pieces of scantling, tenanted together and grooved so as to conduct the mercury towards one corner, where there is a spout to allow it to escape into a vessel, situated so as to receive it. The cistern itself, is made out of a solid block of white marble. It is twenty seven inches long, twenty four inches wide, and ten inches deep."

" The ledges, S S, answer for the same purposes as the shelves in the common pneumatic cistern. The excavation, *w*, is the well in which vessels are filled with mercury, in order to be inverted and placed, while full, on the ledges. There are some round holes in the marble for introducing upright wires to hold tubes, or Eudiometers; also some oblong mortices, for allowing the ends of tubes, duly recurved, to enter under the edges of vessels to be filled with gas;—and in cases of rapid absorption, to afford a passage for the mercury, into vessels, from which it might otherwise be excluded, in consequence of their close contact, with the marble of the reservoir."

---

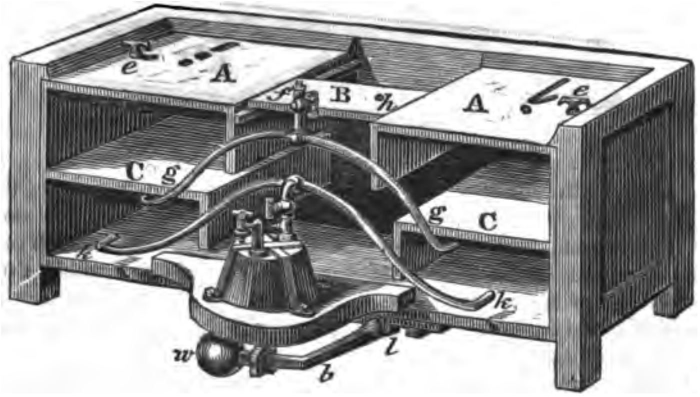
* Prof. Hitchcock, of Amherst College, has one of soap stone.

"This reservoir requires nearly six hundred pounds of mercury to fill it completely."

Water cistern for gases.

Any vessel containing water in sufficient depth to admit of filling the air glasses, will answer in some good degree. There is in the laboratory of Yale College, a pneumatic cistern constructed in 1803, of which an engraving was given in the editions of Henry's Chemistry published by me, and which has been found very convenient. It is furnished with air cells, which may be understood by an inspection of Dr. Hare's figure below. In mine, there were only the upper cells here represented under A A, but divided each into two compartments, and nearly beneath them and under water, were hydrostatic bellows, for throwing in air and gas. From the cells, also, proceeded tubes for the compound blowpipe, but the apparatus in front, representing the arched tubes and the inverted kettle and its treadle, and also the other lower cells under C C, were not in mine.

Hydro-pneumatic Cistern of Dr. Hare.



"The figure, here given, is such as would be presented to the eye, were the front of the cistern removed."

"A A, are two shelves formed by two inverted chests, which are used as cells to contain gas: B is a sliding shelf, over a deep place between the shelves, A A, which is called the well of the cistern."

Fig. 2.

"Fig. 2 affords a view of the lower side of the sliding shelf, in the wood of which it will be seen that there are two excavations, converging into two holes, one of which is seen at *h*, fig. 1.—This shelf is loaded with an ingot of lead at L, to prevent it from floating in the water of the cistern."

"Besides the chests abovementioned, there are two others, C C, near the bottom of the cistern, but not so close as to prevent the water from passing freely into and out of them."

Referring to Dr. Hare's Compendium for the remainder of the description, I will add only, that the inverted kettle by a treadle below, and by the aid of a peculiar internal construction, is made to throw in air through the lower arched tubes, into the cells under C C, which are intended for regulating the height of the water; while it is allowed to escape through the upper arched tubes at their common orifice at *f*. The cells under A A, are for receiving any gas not absorbable by water, and it is easily drawn off at the cocks at *e e*, into vessels standing in the shelves A A.

The student will not suppose that, strictly, any thing more is necessary for a pneumatic cistern, than a water vessel with a fixed shelf or shelves as at A A, and a sliding shelf as at B, and even the latter may be dispensed with by making holes through one of the fixed shelves, and introducing an inverted funnel.

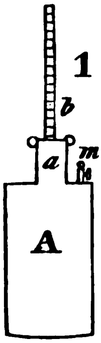
GAZOMETERS.

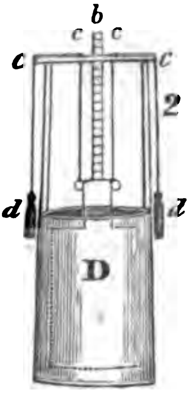
Gazometers are important in many chemical experiments. In contriving the pneumatic cistern mentioned above, it was one object to furnish gazometers in the cistern itself, where most of the gases are prepared; and there was, for many purposes, great utility in the contrivance; but the gases being always under pressure, were of course liable to escape at any leak.

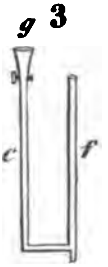
There is so much convenience, however, in occupying with air cells, this otherwise useless space, that I should still recommend this mode of construction, of the pneumatic cistern, so far as the cells are concerned; without attempting any thing farther, except the necessary appendages to draw off the gases.

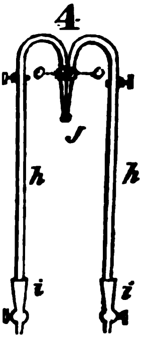
On the whole, I have found the most useful species of gazometer to be the following, which, it will be perceived, is only a modification of the form generally used.

1. The containing air vessel is made of tinned iron, or the thinnest sheet copper, painted and varnished: the form is cylindrical, as at









A, and there is a smaller cylinder, *a*,[*] rising in the centre to receive an interior gas pipe; the rings are to receive the cords that are to suspend the cylinder by passing over pully wheels at *c c*, fig. 2.

2. D is a slightly conical cask, to be filled with water in which A is suspended by the cords already mentioned, and which are weighted at *d d*, so as to keep the air vessel in equilibrio.

3. Fig. 3 represents a tube of copper or lead, which is fastened within the cask D, so that the limb *f* rises in the center and passes up into *a*, fig. 1, when the air vessel is down, and the stop cock *m* is open, for the escape of the common air. The other limb *e* is fastened firmly to the cask at the side.

4. Fig. 4 represents the mouths of two of the interior tubes with additional tubes fitted air tight, with corks through the trumpet shaped orifices, *i i*, and terminating, after curvature, in a frustrum of platinum at *j*. This apparatus of tubes is used for the compound or oxy-hydrogen blowpipe of Dr. Hare, and can be taken off by double jointed screws at *o o*, and also at *i i*, and any other apparatus can be attached. At *b b*, is a thin slip of wood, acting both as a guide and a scale to the air vessel.

It is obvious that if there are two casks and two air vessels, they will form convenient reservoirs for oxygen and hydrogen. Mine contain together fifty gallons, and by means of weights laid on the air vessels, the gases are made to issue at *j*, with all necessary force. Nothing can be more convenient for the compound blowpipe; for the oxygen or the hydrogen blowpipe alone; for the common air blowpipe; for gas lights; for musical tones with hydrogen; for communicating oxygen and hydrogen through a tube to the pneumatic cistern, and for many other purposes, sufficiently obvious to a practical chemist. Smaller instruments upon this principle, are convenient for the respiration of gases, a proper mouth piece being fitted to *e g*, fig. 3.

---

[*] Which may be furnished with a small stop cock, to let off common air.

Part II.—PONDERABLE BODIES.

Introductory Remark.

I shall here repeat what was stated in the Introduction, p. 18, that *a real element is an undecomposable body;* that, *in relation to our knowledge, an element is merely an undecomposed body.*

Our evidence on this subject being only negative, it follows that any body and all bodies, now admitted as elementary, may hereafter be decomposed.

Should we, for argument's sake, admit the improbable result, that all compound bodies may be hereafter reduced to two, the smallest number of principles with which it is possible to form a third body, we should even then not be certain, that these two were real elements; for they might be decomposed into two, three, or four others, and they again into five, six, seven, or eight others, and so on; proceeding from the greatest apparent simplicity, to the greatest complexness.

It is proper to recal to the recollection of the student, that the ancient hypothetical elements, earth, air, fire and water, have all been proved to be compound, and that there are now more than fifty[*] undecomposed bodies, among which are three supporters of combustion, oxygen, chlorine and iodine; about forty metals, and seven combustibles, that are not metallic, namely, phosphorus, carbon, hydrogen, sulphur, nitrogen, boron and selenium. Nitrogen, as already observed, is thrown into this class, as resembling them very much in its relations and character, although it is not in the popular sense a combustible.

INORGANIC BODIES.

SIMPLE SUPPORTERS OF COMBUSTION.

SEC. I. OXYGEN.

1. Name, *Oxygen*,[†] derived from ὀξυς and γεινομαι or γεννάω, signifying, therefore, the generator of acids; a name imposed by the framers of the new nomenclature; the former names were, dephlo-

---

[*] Dr. Turner's 2d edition, gives fifty two, including bromine and selenium.

[†] Several authors, (as Thenard, 5th Ed. Vol. I, p. 166,) consider the name oxygen as improper, because it is not the *sole* acidifier; but it is the great ruling acidifier, it being the sole agent in *almost* all cases, and therefore the name is proper. We might as well reject the name chlorine, because it is not the only greenish yellow body.

gisticated air, vital air, empyreal or fire air, and pure air, which have all yielded to the name oxygen.

2. PROCESSES.

(*a.*) There are several; the most useful is by igniting the purest* black oxide of manganese in an iron bottle† or earthen retort; one ounce of the oxide affords about one hundred and twenty eight cubic inches of gas.

(*b.*) Sulphuric acid 1 part, mixed with the same mineral 2 parts, to the consistence of a paste, and heated moderately, affords this gas; the theory of these experiments will be given hereafter.

(*c.*) Other modes will be mentioned farther on, such as that of heating the chlorate or nitrate of potash,‡ or a mixture of red lead and sulphuric acid; and that from green leaves placed in water in the sun's light, &c. The gas is received in inverted glasses full of water.

3. DISCOVERY—

(*a.*) By Dr. Priestley,§ in England, August, 1774, by heating red oxide of mercury, in a bell glass by the solar focus.

(*b.*) By Scheele, in Sweden, the year after, and without a knowledge of Dr. Priestley's discovery; and also by Lavoisier, at Paris, in the same year.

4. PHYSICAL PROPERTIES.

(*a.*) *Transparent, colorless, tasteless, inodorous, not condensible by pressure and cold, a non-conductor of electricity.*

(*b.*) Sp. gr. 1.1111, air being 1.—*Thomson.*

(*c.*) Weight 33.8888 for 100 cub. in. at the medium temperature and pressure.—*Id.*

(*d.*) Refracts light less powerfully than any other gas.

(*e.*) Becomes luminous‖ as well as hot, by sudden condensation.

(*f.*) It is a non-conductor of electricity.

5. CHEMICAL PROPERTIES.

(*a.*) *It possesses more extensive powers of combination than other substance.*

---

* It is sometimes previously washed with a weak mineral acid, to decompose carbonate of lime, if any is present.

† A wrought iron bottle, with a wide tube about two feet long welded to it, is much the best instrument; it should be coated, every time it is used, with a lute of clay, sand, and flour, applied with the hand and dried before using. A gun barrel answers for a small experiment.

‡ Dr. Thomson says that the first 5th of the gas from nitre is quite pure, and Dr. Hare confirms the statement, that the first portions are quite pure.

§ See Priestley's account in his work on air.

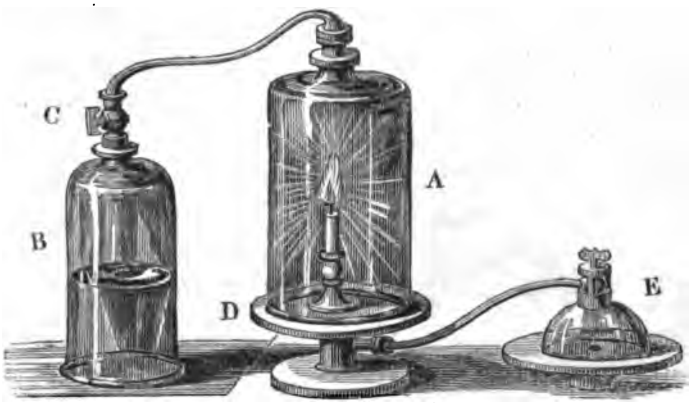
‖ All the gases become hot by sudden pressure, but chlorine and oxygen are the only simple gases that become luminous in this manner; common air becomes luminous by the same treatment, but in a less degree than oxygen, to which gas, this property in air is owing.

(B.) IT ACTS ON COMBUSTIBLE BODIES WITH INTENSE ENERGY, and this is one of its great characteristic, but not altogether peculiar properties.

(c.) *Generally the temperature must be raised, in order to bring on the action.*

(*d.*)* A lighted candle burns brilliantly in oxygen gas. If extinguished, (fire remaining on the wick,) it is instantly relighted with a slight report, and that many times in succession.†

Candle in air, in vacuo, and in oxygen gas.—Dr. Hare.



"Let there be two bell glasses, A and B, communicating with each other by a flexible leaden pipe, a cock intervening at C.—Suppose A, to be placed over a lighted candle on the plate D, which communicates with an air pump plate as represented at E.—It will be found that the candle will gradually burn more dimly, and will at last go out, if no supply of fresh air be allowed to enter the containing bell; if on repeating the experiment, the air be withdrawn by means of the pump, the candle is rapidly extinguished. It is thus demonstrated, that a candle will not burn in vacuo, and that it can burn only for a limited time, in a limited portion of atmospheric air."

"Let the experiment be repeated with the following change. Let the air be exhausted from both vessels, the cock, C, remaining open,

---

* For the experiments under *d* and *f*, a common glass bottle answers sufficiently well.

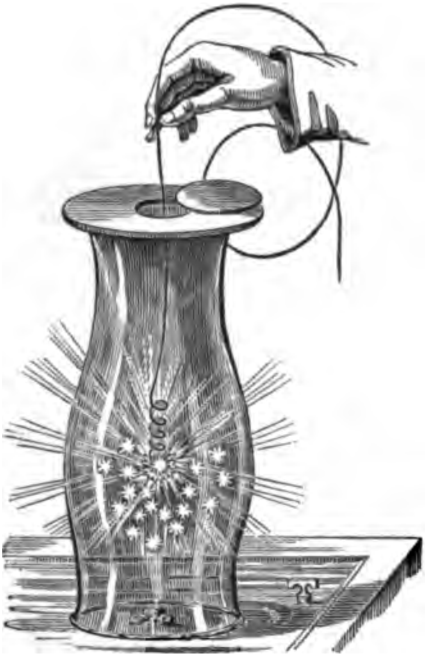
† A quart of oxygen gas, well managed in a bottle, will relight a candle more than fifty times; the bottle should be held mouth upwards, and gently inclined each time the candle wick is presented to it; as the oxygen is consumed or expelled, the bottle must be turned down more and more. A candle in a socket, fixed to a wire, is easily let down into a jar of gas, as represented in the cut.

until the bell, B, is filled with water from the shelf of the pneumatic cistern, on which, for this experiment, it must be placed. The cock being closed, fill the bell, last mentioned, with oxygen gas, from the cell of the cistern. Now lift the bell A, which may be easily done, the pipe having a due flexibility, and introducing a candle, set the bell again on the plate. Next exhaust the air until the candle is nearly extinguished, and then open the cock, so as to allow the oxygen to enter.—The candle will now burn brilliantly for a much longer time, than it had done, when the bell contained atmospheric air."

(*e.*) Ignited charcoal burns intensely in this gas, and the bark with vivid scintillations.

(*f.*) Iron wire or a watch spring, with a lighted sulphur match on the end, burns with bright ignition and sparks, but without flame.

Combustion of iron wire in oxygen gas.—Id.



"Place over the cock of one of the cells of the pneumatic cistern, sufficiently supplied with oxygen gas, a glass vessel, such as is usually employed to shelter candles from currents of air. Let the upper opening of the vessel be closed, by a lid with a central circular aperture, as here represented. Leaving this aperture open, by turning the key of the cock, allow the gas to rise into the vessel from the cell. Next apply a taper to the aperture, and as soon as it indicates by an increased brilliancy of combustion, that oxygen has taken place of the air previously in the vessel, cover the aperture.* Wind a fine wire round any hard cylindrical body of about an inch in diameter.* By these means, the wire is easily made to assume the form of a spiral. Near the end of the spiral, wind it about a piece of spunk about as large as a pin. Having lighted the spunk, remove the cover from the aperture in the lid of the vessel, and lower the end of the wire to which the spunk may be attached, into the oxygen gas. The access of the oxygen causes the spunk to be ignited so vividly, that the wire takes fire and burns with great splendor, forming a brilliant liquid globule, which scintillates beautifully. This globule is so intensely hot, that sometimes on falling, it cannot immediately sink into the water; but leaps about on the surface, in consequence of the steam which it causes the water to emit. If it be thrown against the glass of the containing vessel, it usually fuses it without causing a fracture, and has been known to pass through the glass, producing a perforation without any other injury."

---

* Or, any vessel, large or small, may be filled with oxygen gas, by simply conveying the orifice of a curved tube to the bottom of the vessel, the other end of the tube being connected with a gazometer or other reservoir, from which the gas is allowed to flow ; the atmosphere is thus lifted out and the oxygen takes its place.

(*g.*) *A stream of oxygen gas from a gazometer and blowpipe, directed upon burning charcoal, melts and burns many bodies, as iron, copper and tin,* with brilliant appearances, and the evolution of much heat.

(H.) EFFECT OF THE COMBUSTION.

The oxygen gas is diminished; its ponderable part combines with the combustible body, and both changes its properties and increases its weight; one grain being gained in weight for every three cubic inches of gas absorbed. Combustibles, which like oil, candles, and charcoal, disappear while burning, are not destroyed; they have only passed off in gas, and other diffused forms; with proper care, all the products can be collected again; we can neither create nor annihilate an atom.

(*i.*) *Products of the combination.*—They are either acids, alkalies, oxides or earths; the three last may strictly be included under one head, but it is convenient to divide them. The process of combining with oxygen, is called *oxidation* or *oxidizement,* and the corresponding verb is *oxidate* or *oxidize.*† The oxides are sometimes distinguished by terms derived from their colors, but Dr. Thomson has introduced a nomenclature founded on the Greek numerals, as protoxide, deutoxide, tritoxide, viz. first, second, and third oxide, &c. and ‡peroxide, for the oxide with the most oxygen.

(*j.*) Water, at the pressure of 30 inches, and temperature 60°, if freed from air by boiling, absorbs 3.5 cubic inches of oxygen gas, for every 100 cubic inches of water; by pressure, the quantity is increased, and by great pressure, water will absorb half its bulk, but without any change of properties.

---

* I use a ram rod and binding wire.

† Some use *oxygenize or oxygenate, oxygenizement or oxygenation;* these terms are rather more general, and do not decide whether the product is an oxide or an acid.

‡ From the Latin preposition.

6. *Relation to animal life.*

(*a.*) *Oxygen supports life eminently in respiration*, and is the only agent that is adapted to this purpose; but it is necessary that its great energy should be mitigated by dilution, as will be mentioned again farther on.

(*b.*) A bird will live five or six times as long in a confined portion of oxygen gas, as in the same volume of common air; and several birds will live a short time in oxygen gas, in which others have died; each successive one will, however, in general, live a shorter time than its predecessor.

"Count Morozzo placed a number of sparrows, one after another, in a glass bell filled with common air, and inverted over water :—

The first sparrow lived	*3h.*	*0m.*
The 2d " "	0	3
The 3d " "	0	1

"The water rose in the vessel, eight lines during the life of the first; four during that of the second, and the third produced no absorption. He filled the same glass with oxygen gas, and repeated the experiment.

The first sparrow lived	*5h.*	*23m.*
The 2d " "	2	10
The 3d " "	1	30
The 4th " "	1	10
The 5th " "	0	30
The 6th " "	0	47
The 7th " "	0	27
The 8th " "	0	30
The 9th " "	0	22
The 10th " "	0	21

He then put in two together, the one died in twenty minutes, but the other lived an hour longer."—*Chaptal and Thomson.*

7. *Relation to disease.*—Oxygen gas is eminently salutary in some cases, especially in diseases of the thorax, in paralysis, general debility, &c.*

---

* Oxygen gas, when respired in the human lungs, generally produces a sensation of agreeable warmth about the region of the chest, and some say that they experience a comfortable sensation through the whole body. Chaptal relates the following instance of its effects on a man in consumption. "Mr. De B." says this writer, "was in the last stage of a confirmed pthisis. Extreme weakness, profuse sweats, and in short, every symptom announced the approach of death. One of my friends, Mr. De P——, put him on a course of vital air. The patient respired it with delight, and asked for it with all the eagerness of an infant at the breast. During the time that he respired it, he felt a comfortable heat which distributed itself through all his limbs. His strength increased with the greatest rapidity; and

8. *Effect on the color of the blood.*—If blood be suspended in oxygen gas or agitated with it, or even with common air in a glass tube, it turns it of a brilliant vermilion color; the nature of the change is to be mentioned hereafter more particularly; we may however remark at present, that it acts on the blood principally, by imparting oxygen and detaching carbon.

9. *It is found in more combinations and in greater quantities than any element.**—It is found in the atmosphere, in all waters and watery fluids, and in all natural fluids, except perhaps naptha and mercury. It exists in animals and plants; in stones, rocks, and metallic oxides, and in acids, salts, earths, and alkalies; it possesses therefore the highest importance, and without knowing this agent, we could understand little of the real constitution of things.

What has been called the modern theory of chemistry, was occupied principally in unfolding the agencies of oxygen, and this exposition still constitutes the most important part of the science.

10. *Polarity.*—It goes to the positive pole in the electro-galvanic circuit, and is therefore considered as electro-negative.†

11. *Its combining weight.*—Hydrogen being unity,‡ oxygen is represented by 8, because these are the proportions in which these elements exist in water.

As its combining weight is "smaller than that of most bodies, it is inferred that it approaches nearer than they to the elementary or

---

in six weeks, he was able to take long walks. This state of health lasted for six months; but after this interval he relapsed; and being no longer able to have recourse to the use of vital air, because Mr. De P—— had departed for Paris, he died. I am very far, adds Mr. Chaptal, from believing that the respiration of vital air ought to be considered as a specific, in cases of this nature. I am even in doubt whether this powerful air is perfectly adapted to such circumstances; but it inspires cheerfulness, renders the patient happy, and in desperate cases, it is certainly a most precious remedy, which can spread flowers on the borders of the tomb, and prepare us in the gentlest manner for the last dreadful effort of nature."

Thenard relates that of three men who had been suffocated by sulphuretted hydrogen gas, in cleaning a privy, two died almost immediately, and the third being almost dead, was made to respire oxygen gas from a bladder, and it rallied his powers so that he sat up for a moment, but soon fell back and died. In a case related in the Am. Jour. Vol. XVI, p. 250, by Dr. Muse, of Cambridge, Maryland, there was the most complete success, a favorite hound that had been for several hours completely drowned, having been perfectly restored to life, and gradually to all his functions in consequence of the injection of oxygen gas into his lungs; the very first inflation of the lungs produced a shrill yelp from the animal. For other remarkable cases, see also Am. Jour. Vol. I, p. 95, and Dr. Thornton's various Reports in Tilloch's Philos. Mag.

* Limiting our estimate, of course, to the bodies with which we are acquainted.

† Several respectable modern authors make this fact the foundation of an arrangement of chemical bodies.

‡ Several authors have adopted oxygen for unity; Dr. Thomson makes it 1, Dr. Wollaston 10, Berzelius 100, &c.

simple state;"* this might have been said with still greater truth, of carbon and hydrogen.

Remarks.

Oxygen unites with every simple body, but it has neither acid nor alkaline properties. It is the agent in all common cases of combustion, which in most instances, is nothing more than rapid oxidation, with the emission of heat and light; and a slow combination of oxygen often goes on without either; common iron rust is produced in that manner.

Combustion and respiration have the same effect in vitiating the air; the air in which an animal has died, will not support combustion, and the air in which a combustible will not burn, will not support animal life.

Oxygen is involved in the chemical study of all bodies, simple and compound. The term oxygen means strictly the ponderable part of oxygen gas; the material part is known only in combination; it has never yet been isolated so as to exhibit it separately; in its gaseous form, it is combined with caloric and light, and probably with electricity.

It appears to exist no where in nature, in a pure and disengaged state, and we always obtain it for use by evolving it from one of its combinations. Healthy leaves of vegetables, acted upon by the direct sun beams, throw it off incessantly into the atmosphere, and it is supposed to be a principal means of recruiting the waste of oxygen which arises from combustion, respiration, and other natural processes. In the dark, a different gas, the carbonic acid is said to be disengaged; the subject will be resumed in giving the history of that gas.

It is fortunate that oxygen gas can be easily and abundantly obtained from the native oxide of manganese, as there is scarcely any other from which it could be obtained at all, and no other which could supply the demands of chemistry and the arts.

Nitre is perhaps the easiest resource for affording oxygen gas, but only the early portions are pure; a little may be heated to low redness in a gun barrel, but we should avoid the mouth, as the melted nitre is apt to boil up, congeal above the ignited portion of the tube, and thus acting like a wad, by and by, after a cessation, the gas causes an explosion, by which the hot nitre is driven about. Every thing connected with the history of oxygen, is elegant, beautiful, and instructive; without it there would be no beginning of animal life, nor any adequate means of producing and regulating heat.

---

* Murray, Vol. I, p. 407.

SEC. II. NITROGEN OR AZOTE.—THE ATMOSPHERE.

NITROGEN.

1. *Name.*—As it is the basis of nitric acid, it is now called nitrogen; its former name was from α, a Greek privative, and ζωη, life, signifying that which destroys life; but the name is not distinctive, many other gases being azotic.

2. *Discovery*—by Dr. Rutherford, at Edinburgh, 1772; Lavoisier first separated it from the atmosphere, in 1775, and Scheele, about the same time.

3. *Mode of obtaining.*

(*a.*) Burn phosphorus in a floating saucer or other earthen dish under a bell glass over water; the acid fumes are absorbed in half an hour by the water, and sooner, if agitated with it; and nitrogen gas slightly phosphorized, remains.

Solution of caustic potash, agitated with the gas in a bottle, quickly separates both the phosphoric acid, and a little carbonic acid which is sometimes mingled with it.

(*b.*) With a gentle heat, dilute nitric acid, sp. gr. 1.20, acting on lean muscle in a glass retort, evolves nitrogen.

(*c.*) Iron filings and sulphur being mixed and moistened, and placed in a saucer under a bell glass; the oxygen is absorbed in three or four days, and nitrogen remains. Other methods will be mentioned farther on.

4. PHYSICAL AND CHEMICAL PROPERTIES.

(*a.*) *Transparent, colorless, inodorous, tasteless, not sensibly absorbed by water.*

(*b.*) Sp. gr. .9722, air being 1.—(*Thomson.*) 100 cub. in. weigh 29,652 grains.

(*c.*) Its refractive power is very feeble.

(*d.*) *Combines with oxygen,* and forms several very important compounds—nitric acid, the nitrous acids, nitric oxide gas, and nitrous oxide gas.

(*e.*) *No combination results from a mere mixture of the oxygen and nitrogen;* owing to the repelling power of caloric, they would probably remain forever in mixture, without change; but they will unite, if in the nascent state, or, if one of them is in that condition.

(*f.*) *Combined with oxygen by electricity,* nitrogen forms nitric acid.

(*g.*) *Still it is not a combustible in the common sense of that word;* it does not fire by the approach of a candle to the mouth of a vessel containing it, nor if previously mixed with oxygen gas.

(*h.*) *It is fatal to combustion.*—A burning match, candle, phosphorus, or any burning body is extinguished by immersion in this gas; even potassium, although intensely heated by galvanism in nitrogen, produces no change; it is therefore not a supporter of combustion.

(*i.*) Water deprived of its air by boiling, absorbs about one and a half per cent. of this gas; or, according to Dr. Ure, 100 volumes of water absorb about one of this gas; Mr. Dalton states it at 2.5.

5. EFFECTS ON ANIMAL LIFE.

(*a.*) *Fatal*, if breathed pure; an animal immersed in it, immediately dies.

(*b.*) *Kills by suffocation merely;* it is not directly noxious, and exerts no positively injurious influence on the lungs; an animal is drowned in it as it would be in water.

6. COMPOSITION.

(*a.*) *Unknown;* but it is suspected to be compound; Berzelius believes it to be an oxide of an unknown base.*

(*b.*) *Contained in animal matter*, and is equally abundant in herbivorous and graminivorous, as in carnivorous animals.

(*c.*) *Plants do not generally contain it.*

(*d.*) *It is an element*, according to the present state of our knowledge.†

7. IMPORTANCE AND DIFFUSION.

(*a.*) It forms the basis of animal substances; of them it is the characteristic element, and it gives origin to the ammonia and the prussic acid, which are generated during their decomposition.

(*b.*) *It is found in the cruciferous plants*, cabbage, mustard, &c.; in the fungous tribe, mushrooms, &c. and in all plants that putrefy with an animal odor.

(*c.*) *Its properties are interesting principally in combination;* especially in animal matter; in the nitric compounds; in ammonia, and with chlorine and iodine; for an account of which, see the sections containing those subjects.

8. POLARITY.—*It resorts to the negative pole in the electro-galvanic circuit*, and is therefore considered as electro-positive.

9. Its combining weight is 14, hydrogen being 1.

Nitrogen is possessed rather of negative than of positive properties, but in combination, it produces bodies of a highly active and interesting character; some of the most powerful fulminating compounds contain it.*

---

* Thomson's Annals, II, 284.

† When ammonia, an alkali which contains nitrogen, (or either of its salts,) is galvanized with mercury, it converts that metal into an amalgam, which creates a suspicion that its base is metallic; but Gay Lussac and Thenard say, that this amalgam is immediately resolved into mercury, ammonia, and hydrogen, even when water is not present, and that, therefore, it is composed of these three substances directly united; but, there may be metallic matter in both ammonia and hydrogen, or in hydrogen alone, because it is contained in ammonia, and it is possible that even nitrogen may be an oxide of hydrogen.

THE ATMOSPHERE.

PHYSICAL PROPERTIES.

(*a.*) *Transparent, colorless, inodorous, only slightly absorbed by water;* a bad conductor of heat and of electricity; the latter when accumulated, passes through the air in a spark, but is diffused through a vacuum in the form of a luminous cloud.

(*b.*) *The azure color and other hues in the atmosphere, are produced by reflected light.*

(*c.*) *As we ascend, the sky grows darker,* and at a great height, the stars with the lustre of silver, are contrasted with a basis of black.

(*d.*) *Specific weight,* 1.; it is unity for all other aëriform fluids; 100 cubic inches, at the medium temperature and pressure, weigh 30.50 grains.† Compared with water, it is $\frac{1}{820}$ of the weight of that fluid. Gallileo ascertained in 1640, that it has weight, and Torricelli introduced the barometer tube in 1643.

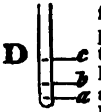
(*e.*) *Absolute weight;* at the ocean level, about fifteen pounds on the square inch, equal to thirty four feet of water, and thirty inches of mercury.—*Henry.*

(*f.*) *As we ascend, the heights being in an arithmetical ratio, the weight decreases in a geometrical ratio;* at three miles elevation, it sustains 15 inches of mercury; at six miles, 7.5 inches; at nine miles, 3¾ inches; at fifteen miles, about 1 inch.—*Id.*

Air is compressed in direct proportion to the force applied. Double the force will reduce it to half the volume; double the force again, and its volume will be again reduced one half, that is, to one quarter of its first volume, and so on. A force has been applied to it, equal to 110 atmospheres, and the law stated above, was found still to hold good.‡

---

* In the Eng. Jour. of Science, Vol. XIX. 17, Mr. Faraday has given an account of an ingenious method of detecting minute portions of nitrogen, by the formation of ammonia. D is a glass tube, four or five inches long, and one fourth of an inch in the bore. At *a*, there is some zinc foil; at *b*, a piece of potash; at *c*, a piece of turmeric paper moistened with pure water, at the lower end, which is two inches above the potash; heat the lower end of the tube only in the spirit lamp so as to melt the potash, and almost instantly, the moistened paper will be reddened, indicating an alkali, and it is evident that it is ammonia, because the color is discharged when the paper is withdrawn, and the colored part laid on the warm tube.



Sea sand *handled* after ignition, yields ammonia, which is discovered by this treatment.—*Ib.*

† Shuckburgh 30.199.—*Brande.*

‡ Ed. Jour. Science, No. VIII, 224.

Mr. Perkins states, that he has applied to it a pressure of 2000 atmospheres, and he supposed that he had thus compressed it into a liquid, but as this liquid was permanent under the common pressure, it is probable it was water only. As we descend below the surface of the earth, the density and pressure of the air continue to increase in the same ratio. "In very deep mines, water will not boil till heated 3 or 4 degrees above 212°[*].—*Murray.*

(*g.*) The greater part of the atmosphere is within three or four miles of the earth's surface.

(*h.*) The phenomena of refraction indicate that the atmosphere is at least forty or forty five miles high.

(*i.*) *Dr. Wollaston thinks that the atmosphere has limits fixed by gravity*, counteracting the elasticity imparted by caloric, (Phil. Trans. 1822,[†]) and on account of the absence of refraction, (the heavenly bodies not being disturbed in their apparent position,) it is asserted that neither the sun nor Jupiter has any atmosphere; hence the earth's atmosphere is not indefinitely divisible, and does not extend to those bodies, and therefore it is thought that its ultimate atoms must be indivisible, and this is regarded as a direct proof of the truth of the atomic theory, or, in other words, of the existence of indivisible atoms or particles.

(*j.*) WINDS are produced by the ascent of rarefied air arising from the pressure of colder and heavier air towards the heated place. Thus, as already stated, page 68, are produced the trade winds, monsoons, and land and sea breezes, and the irregular winds.

(*k.*) *The draught of a chimney is owing to atmospheric pressure;* the column of air in the chimney rarefied by heat, is lighter than the adjacent column of colder air, and therefore ascends from the preponderance of the latter.

(*l.*) *The refractive power of the air is* observed in the elevation of ships and other objects near the horizon, and in the effect on the heavenly bodies in the same situation, causing them to emerge sooner when rising, and to linger later when setting.

(*m.*) It has been already stated that the higher regions of the atmosphere are cold; the temperature in the lower regions, diminishes at the rate of one degree for every three hundred feet.

2. CHEMICAL PROPERTIES.

(*a.*) *Air supports combustion,* as every one knows.

(*b.*) *It generates acidity* in vinous fluids.

(*c.*) *It oxidizes some of the metals,* at the common temperature, and most of them at ignition.

---

[*] It is calculated, that at 46 miles below the surface, air would have the density of quicksilver.

[†] For an excellent analysis of this curious paper, see Murray, 6th Edit. Vol. I, p. 418.

(*d.*) Very great rarefaction diminishes, and even destroys its power of supporting combustion.

(*e.*) Great condensation does not increase the intensity of the combustion, although it is sustained for a longer time.

(*f.*) Mixture with various gases diminishes it.*

3. COMPOSITION, IN VOLUME, 80 NITROGEN, 20 OXYGEN—BY WEIGHT, oxygen - - - - 22.22
nitrogen - - - 77.77

100.00 very nearly.†

This proportion of oxygen is undoubtedly that which is best adapted to the support and comfort of human life, and to the convenience of all the animal creation. Experiments have proved that animals compelled to breathe oxygen gas alone, soon become feverish from excess of stimulus, and life is eventually destroyed by the intenseness of its own functions; just "as a candle burns brighter in oxygen gas, and is more quickly consumed, so in this gas, the flame of life would be more vivid, but sooner burnt out."

Most chemists have stated the composition of air at 21 per cent. of oxygen. Dr. Henry states that he could never satisfy himself whether it was 20 or 21; Dr. Hare obtained very constantly 20.66, but 20 corresponds with the theory of volumes, viz. 1 to 4, and also of definite proportions by weight, that is, 1 proportion of oxygen 8, to 2 of nitrogen 28. Still the greater number of chemists do not admit that the atmosphere is a chemical compound.

4. MEANS OF ANALYSIS.

They are numerous; every substance which abstracts oxygen without returning any thing, may be employed for this purpose.

(*a.*) Phosphorus is effectual, either by slow or rapid combustion; the latter is the most convenient process, and if we subtract $\frac{1}{40}$ of the volume on account of the vapor of phosphorus dissolved, in the nitrogen, the result will be accurate.

(*b.*) Iron filings and sulphur moistened, and standing in contact with a confined portion of air remove the oxygen.§

(*c.*) Quicksilver heated in the confined air of a retort, forms oxide of mercury.

(*d.*) Many other things to be mentioned in their place, produce a similar effect; see hydrogen, nitric oxide gas, hydro-sulphurets, &c.

In all these cases, oxygen is abstracted and nitrogen gas is left, and we know of nothing which will remove the latter gas, and leave the oxygen. The process of analysis of the air is called eudiometry, the instrument, an eudiometer.[*]

---

* See Henry, 10th Lon. Ed. Vol. I, p. 296.

† Thomson's Principles of Chemistry, Vol. I, p. 100. ‡ Turner.

§ If they stand too long, hydrogen may be evolved from the decomposition of water.

5. CONDITION OF THE ELEMENTS OF THE ATMOSPHERE.

(*a.*) *It has been already stated, that most chemists suppose the atmosphere to be a mixture of the two gases.*—In favor of this view, it may be said that there is not, as in most cases of chemical combination, any change in volume; 4 volumes of nitrogen and 1 of oxygen, forming precisely 5 volumes of the mixture; the refractive power and the agency in combustion and respiration, is just what would arise from the operation of the mixed gases, and even water, in a degree, separates them, because ebullition expels from rain water more than 28 per cent. of oxygen;[†] the extended surface of the drops of rain being peculiarly favorable to the efficiency of a weak affinity; also, a small quantity of air agitated with a large quantity of water, has all its oxygen absorbed, and but little of its nitrogen. On the other hand, as the proportions, both by volume and weight, correspond with the theory of definite proportions; as there is no inequality in the mixture arising from the difference in specific gravity, the atmosphere being every where the same;[‡] even if the gases are not combined, the winds would tend greatly to preserve, in equable mixture, aëriform fluids whose gravity is so nearly equal.

(*b.*) *Perhaps it is, rather, a feeble combination.*—Analogous to the many which exist between palpable substances where the properties are not altered. (See p. 159.) There is no improbability that gases may be united by a very feeble affinity, and a strong one would, in this case, be incompatible with the exigencies of animal and vegetable life, and with the demands of combustion. It is indispensable that the atmosphere yield up its elements readily.

6. *Constancy of the proportions.*

(*a.*) *They never vary, except from the operation of limited local causes*, such as combustion and respiration. The air which Gay Lussac brought down from 21.735 feet above the earth,[§] contained the regular proportion of oxygen; so does that obtained in the deepest mines; that transported from Egypt and the African sands, and from Mont Blanc and Chimborazo, had the same constitution.*

---

[*] The term alludes to the health of the atmosphere, as it was supposed to be affected by the proportion of oxygen; the Greek particle ευ, signifying well, and Διὸς, the atmosphere, derived from Jupiter, which in Greek is Ζεὺς, Gen. Διὸς, used for the atmosphere.

[†] Edin. Jour. No. 8, p. 211, quoted by Dr. Turner.

[‡] Mr. Dalton's views of the constitution of the atmosphere and of mixed gases, are opposed to this opinion. See Henry, Vol. I, p. 299, 10th Lon. Ed. In a vertical tube, or in two vials thus connected by a tube, hydrogen gas will in a few hours descend, and carbonic acid gas ascend, so as to mix with each other contrary to gravity. Still, in chemical experiments, we find it important to favor the mixing of gases of remarkably different specific gravity, by adding the lightest, last; otherwise the mixture will be imperfect and tardy. The great mobility of gases, and the waves and currents so easily produced in them by even slight variations of temperature, might be expected to favor their mixture in the course of time.

[§] At that height, an exhausted bottle was opened, filled with air, and then closed; after his descent, it was opened under water, which rushed in and filled half of it, thus proving the great rarity of the air.

(*b.*) *This constancy, as has been generally supposed, is maintained by the agency of the vegetable kingdom.*—See carbonic acid and vegetables. Living vegetables in the sun's light, give out oxygen gas and decompose carbonic acid for food; in the night, they absorb oxygen and give out carbonic acid, but Priestley and Davy say, that they give out more oxygen than they consume, and therefore they purify the air.

(*c.*) According to Prevost, 100 years would consume only $\frac{1}{7200}$th part of the weight of the oxygen in the atmosphere, making due allowance for all the consuming processes that are going on, and therefore if they had gone on even at the same rate from the creation of man, the consumption would have been but the $\frac{1}{120}$ part, and doubtless it has not been half of that, that is, $\frac{1}{240}$. Some have supposed, that volcanic fires expel oxygen from various mineral bodies; some, that nitrogen is absorbed into the bodies of animals, and others, that hydrogen is obtained by plants from the decomposition of water; all of which processes would either throw oxygen into the air, or tend to give it a preponderance, but none of these suggestions are proved to be true.

7. AGENCY IN RESPIRATION.

(*a.*) *Animal life universally, in all its forms, is sustained by the oxygen of the air.*

(*b.*) *The nitrogen appears to be merely a diluent,*† and not to act except under certain peculiar circumstances, but it is not improbable that it answers some positive purpose in the animal economy, whose nature is not yet understood.

(*c.*) *The principal effect in respiration, appears to be the abstraction of carbon from the blood.*—See carbonic acid and respiration.

7. THERE ARE OTHER BODIES IN THE ATMOSPHERE.

(*a.*) Perhaps the only ones that are constant, are carbonic acid, about $\frac{1}{1000}$ or $\frac{1}{2000}$, and it never exceeds $\frac{1}{100}$ and aqueous vapor; $\frac{1}{100}$‡ by weight. Saussure found carbonic acid at the top of Mont Blanc, and it exists at every height hitherto attained, but the aqueous vapor varies with the temperature; air at 60° may contain 10 grains of water to a cubic foot, and 4.5 at 43°, and the quantity increases in a high ratio as the temperature is raised. On high mountains, it is very small; caustic potash remained dry on the peak of Teneriffe, at 12,176 feet above the sea.

---

* Mr. Faraday's analysis of air from the Arctic regions, shows a decided and constant difference between it and the air of London, of at least 1.374 per cent. See Appendix to Parry's 3d voyage, Lond. Ed. p. 240. No explanation is given to account for the cause of this difference, but I have little doubt that it is owing to the deficiency of vegetation in high northern latitudes.—(*Communicated.*) J. T.

† We cannot be positive on this point; it is certainly possible that it has some more important agency.

‡ Mr. Dalton found it rather more than this in the air which an assembly of two hundred people had breathed for more than two hours.

(*b.*) *These adventitious things probably vary in their proportion.*

(*c.*) *Besides these, there are other bodies.*

Various inflammable gases, from marshes and stagnant waters, from putrefaction, &c.

Ammonia, from the latter cause, and from some plants.

Vapors and effluvia, from every volatile thing, from fluids, flowers, &c. producing odors and aroma.

The matter of contagion.—It is too subtile as yet for our processes, doubtless it is something aërial, more subtile than any gas yet known. It is combated successfully by chlorine, and to a degree, by acid gases.

"Seguin examined the infectious air of a hospital, the odor of which was almost intolerable, and could discover no appreciable deficiency of oxygen, or other peculiarity of composition."—*Turner.*

Upon the usual estimation of 21 per cent. of oxygen in the air, its contents will be, including only those bodies whose existence has been proved to be constant.

Nitrogen gas,	77.5 by measure,	75.55 by weight.
Oxygen gas,	21. "	23.32 "
Aqueous vapor,	1.42 "	1.03 "
Carbonic acid gas,	.08 "	.10* "

Dr. Prout discovered that the specific gravity of any gas is obtained by multiplying its combining weight by .555, which is half the sp. gr. of oxygen gas, air being 1. or 10.; half the sp. gr. of oxygen is taken because half a volume of oxygen represents its combining power. The above rule applies to gases whose equivalents are estimated with reference to oxygen as unity; if hydrogen be unity, then multiply the equivalent by that scale, by .555 as before, and divide the product by 8, which is the combining weight of oxygen upon that scale. Or the same result will be obtained by multiplying the equivalent upon the hydrogen scale, by the number expressing the sp. gr. of hydrogen, namely, 0.0694.—*Id.*

Remarks.

If we could suppose our atmosphere to be removed, (the laws of heat and of pressure remaining as they now are,) another atmosphere would be immediately formed, consisting of aqueous vapor, and of every thing else that could, at the given temperature, assume the aëriform condition; this process would go on until the pressure reacted with sufficient power to become mechanically a substitute for the present atmosphere. With similar physical laws, we cannot therefore understand, how any of the heavenly bodies can be without atmospheres, of some kind or other.

---

* Murray, I, 433.

SEC. III.—HYDROGEN—WATER—HARE'S BLOWPIPE.

HYDROGEN.

The name is derived from υδωρ *and* γενναω, *or* γεινομαι, *signifying the generator of water;* the popular name is inflammable air; the miners call it wild fire.

1. Discovery.

It was probably known to the ancients, but Mr. Cavendish, A. D. 1766, first proved it to be a distinct gas,* as Dr. Black had done nine years earlier with respect to carbonic acid gas, which was the first aëriform body, other than common air, whose existence was established, and hydrogen was the second.†

2. Process.

It is always obtained, directly or indirectly, from the decomposition of water.

(*a*.) Fragments of zinc, or iron filings, or turnings, 1 part, sulphuric acid 2 parts, water 5 or 6 parts; add the water to the metal; then the acid by separate portions, with intermediate agitation, the vessel being held under a chimney, till the effervescence comes on, when the gas must be received over water, in inverted vessels filled with that fluid. A glass retort, or a glass flask, furnished with a bent tube is all the apparatus that we need. A vessel of lead, or even of plate tin, will answer very well, but its opacity is an inconvenience. Muriatic answers nearly as well as sulphuric in obtaining this gas, but the latter is much cheaper.

(*b*.) It is obtained still purer, by the decomposition of water, by iron; see water.

(*c*.) *A purer gas.*—Hydrogen gas as obtained by the above processes, is not quite pure; if washed with a little lime water, or caustic potash, it is deprived of carbonic acid, and of sulphuretted hydrogen, which sometimes arises from sulphur in the zinc, and by being passed through alcohol, it loses its odor, which is probably owing to a volatile oil,‡ supposed to be generated between the carbon in the metal and the hydrogen. A little carburetted hydrogen is very apt to remain; and to have the gas absolutely pure, the zinc must be previously distilled. It sometimes has a little zinc or iron suspended or dissolved in it.

---

* Phil. Trans. v. 66. p. 144.

† Carbonic acid gas was discovered in 1756 or 7; hydrogen in 1766; nitrogen in 1772; oxygen and chlorine in 1774. These important discoveries laid the foundation of the pneumatic chemistry.

‡ Which, on diluting the alcohol, makes its appearance, after a few days, upon the surface of the water. Other authors suggest that arsenical particles derived from the zinc, cause the smell.

3. Theory of the process.

The acid is not altered, but the water is decomposed; its oxygen passing to the iron, converts it into an oxide, and its hydrogen is evolved; the acid unites with the oxide of iron, and forms sulphate of iron, which appears in green crystals, as soon as the mixture is cold. How the acid operates to favor the decomposition is not altogether clear.*

4. Physical properties.

(*a.*) It is colorless and transparent. As commonly obtained, it has a smell slightly fetid. If obtained over mercury, the odor is much diminished. It is scarcely absorbed by water, unless it has been freed from common air, when 100 cubic inches of that fluid take up 1½ inches of the gas; with strong pressure the water absorbs one third of its volume.

(*b.*) *It refracts light more powerfully than any gas*, agreeably to the general law with respect to inflammable bodies; ratio 6.6—air being 1.†

(*c.*) Specific gravity 0.694, air being 1, just 16 times lighter than oxygen; weight 2.116 grs. for 100 cub. in. at the medium temperature and pressure.‡ One cubic inch weighs but little more than $\frac{1}{50}$ of a grain, and fifty cubic inches but little more than one grain; it is the lightest form of matter hitherto obtained. "It is about 200,000 times lighter than mercury, and 300,000 times lighter than platina."—*Hare.*

---

* This used to be called a case of disposing affinity; the acid being *disposed* to unite with the oxide of iron *about to be formed*, by the transfer of the oxygen of the water to the iron; this explanation appears to be no more than *verbal*, as the oxide of iron cannot exert an attraction before it is in existence; but if, as suggested by Murray, the acid be supposed to exert, simultaneously, an attraction, both for the oxygen of the water, and for the iron, it may thus aid the combination of the former with the latter, and then the acid will combine with the oxide of iron. But there is no evidence, except that which is afforded by the fact in question, that such an attraction exists between the acid and the oxygen, and the acid and the iron. It appears to me better to say that we do not understand it, and to wait till we do, before we attempt to explain the fact. The heat generated by the action of the acid and water, will not explain the decomposition, for the *cold* diluted acid will rapidly evolve hydrogen gas from iron; it grows hot, it is true, during the action, but the heat is not the cause, it is the effect of the action. There is another theoretical difficulty in this experiment. The rapid evolution of gas, and especially of one whose capacity for heat exceeds that of all known bodies, ought not, upon the received theory of heat, to evolve that power; the mixture ought to grow cold. Again, the crystallization of the sulphate of iron is rapid, and begins even before the mixture is cold, and proceeds the more rapidly the colder the liquor grows; but the evolution of a solid from fluids ought to produce heat.

† Henry, vol. 1. p. 151.

‡ Thomson.

(*d.*) Balloons* are filled with it. The principle of balloons is very well exhibited by filling soap bubbles with hydrogen gas, or, better still, with the explosive mixture of oxygen and hydrogen; they will rise in the atmosphere; the former rapidly, the latter more quietly, and the flame of a candle will fire them as they pass; in the latter case there is a considerable explosion. The solution of soap should be strong, and used cold, and a metallic pipe will allow the bubbles to be more easily disengaged than one of clay. If a dish of strong soap water be blown up full of bubbles of the mixed gases, it detonates powerfully, when fired by throwing a burning match into it. A bladder, filled in the same manner, may be fired by piercing it with a sharp wire, fixed to a pole, and having, appended to the wire, a burning rag moistened with spirit of turpentine.

(*e.*) Musical tones† are produced when a small jet of this gas is burned in a glass or other tube. They are produced also by carbonic oxide, coal gas, olefiant gas, and vapor of ether, burning in a jet; the sounds are produced in bottles, flasks, and vials; and globes, from seven to two inches in diameter, give very low tones. The report is considered by Mr. Faraday, agreeably to the views of Sir H. Davy, as only a continued explosion.‡

5. CHEMICAL PROPERTIES.

(*a.*) *Hydrogen possesses extensive powers of combination*, as will be seen in the history of other bodies, especially of chlorine, iodine, sulphur, carbon, &c., and of animal and vegetable substances.

(*b.*) ITS INFLAMMABILITY IS ITS MOST IMPORTANT PROPERTY.

(*c.*) A candle kindles a jar of it, but is itself extinguished by immersion in the gas, and is relighted if the wick again touch the flame; see the annexed figure of Dr. Hare, which needs no explanation.

---

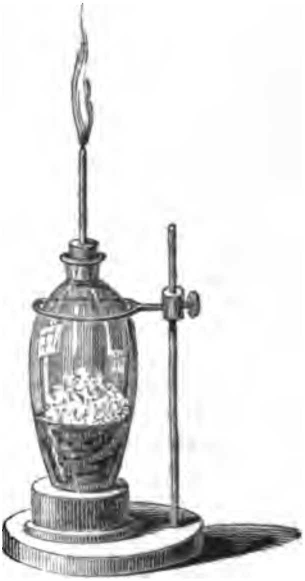
* For some curious and amusing speculations respecting the *possible* uses of balloons, see the Am. Jour. Vol. XI, XII and XIII. Gay Lussac, who ascended till the mercury in the barometers stood at 11 inches, ascertained, that magnetism and electricity existed at that height, in undiminished energy, and that the proportion of oxygen and nitrogen, was the same as at the surface of the earth.

† A jet of flame from one of the gazometers, p. 184, is admirably adapted to insure the success of this pleasing experiment. By turning the key, the jet is accurately regulated, and a great variety of tones, from the most acute to the most grave, is easily produced by using tubes of different materials, diameters, length and thickness; hardly any tube comes amiss, and the same tube will give a variety of tones, if moved up and down, while the flame is in it.

‡ Eng. Jour. of Science, No. 10.

It is plain from this experiment, that hydrogen gas is a combustible, but not a supporter of combustion; it burns where it is in contact with the air, but will not permit a candle to burn in it; on the contrary, oxygen gas causes the candle to burn more rapidly, but, when it is withdrawn, the gas does not itself burn.

(*d.*) Hydrogen gas burns in jets and in many pleasing forms, as is illustrated by the following figure.



The bottle contains the materials to afford the gas, which is kindled at the orifice of the tube, (the common air having been allowed previously to escape,) and the jet is called the philosophic candle. The flame is very pale, but Dr. Hare, whose cut is annexed, ascertained, that the addition of one seventh of spirit of turpentine to the materials, would "obviate this defect."

(*e.*) If mingled with common air, 5 or 6 volumes, and hydrogen gas 2, it explodes on contact with the flame of a candle.

(*f.*) More violently with oxygen gas 1 part, and hydrogen 2, by volume. This mixture should not be exploded in glass vessels, unless in small quantities, and unless the glass is strong, and well annealed. It is better to use tubes of tin plate, or sheet copper; a cylinder of the latter, closed at one end;* or two cones joined at the base, and furnished with a mouth that can be corked firmly, and with a touch hole, make a good discharging pistol. It is first filled with water; then with the mixed gases, and then kindled by a burning candle, or sulphur match, applied at the touch hole.† Hydrogen gas burns in volume with a yellowish flame, sometimes with points and sparks of red.

(*g.*) Hydrogen gas, from its levity, escapes rapidly from vessels held with their mouths upward; but it remains a good while in contact with the air, without escaping, if their mouths are in the reverse position. It may be turned upward into a vessel full of air, and will expel it, and take its place.

---

* If this mixture be allowed to escape from beneath water, the bubbles explode violently on touching a flame at the surface; a glass vessel should never be used in this experiment.

† If the double cone be filled with hydrogen and held with the mouth downward, leaving the touch hole at the top open, the gas will slowly escape and may be kindled, being gently pressed upwards by the atmosphere. If when partly burned, the instrument be turned upwards, the mixed gases will explode.—J. G.

(*h.*) Suspend, out of the water of the pneumatic cistern, a tall narrow jar, full of the gas, keeping a glass plate over its mouth, until it is fixed in its place: then withdraw the plate without agitation; on putting a burning candle to the mouth, a quarter of an hour after, the gas will take fire with the usual slight explosion, and will then continue to burn quietly away, thus proving that owing to its levity, the pressure of the atmosphere had kept it in its place.

(*i.*) Reverse the experiment, by filling the same jar again with the same gas; cover its mouth with the glass plate, and turn it up; let an assistant hold a candle a foot above, and when the plate is withdrawn, the gas, now rapidly rising, will take fire as it is passing upward, and will exhibit a volume of flame in the air: the same pressure which in the former experiment kept it in its place now forces it to rise.

6. EFFECTS ON ANIMAL LIFE.

It is hostile to life, but not instantly fatal.

(*a.*) The lungs may be inflated with it a few times in succession, and it may be blown out without injury.* It produced in Mr. Maunoir and Mr. Paul, at Geneva, a soft, shrill, and squeaking voice, when they attempted to speak, after breathing it.

(*b.*) Frogs placed in hydrogen gas will suspend their respiration; they have been known to do it for 3½ hours at a time.

(*c.*) In mixture with oxygen, it may be substituted for the nitrogen, and a respirable atmosphere might thus have been made; but, the mixture would have been explosive, and the hydrogen would probably have separated from the oxygen in consequence of its levity.

(*d.*) It kills by suffocation, merely or principally, as water does.

(*e.*) It is not noxious to plants, and some, it is said, even absorb it.

7. NATURE OF HYDROGEN.

It is an element in relation to our knowledge, and probably it is a real element. It is a simple combustible.

8. ITS IMPORTANCE AND DIFFUSION.

(*a.*) It is probably, next to oxygen, the most important element; it is exceedingly abundant, and its compounds meet us almost every where.

(*b.*) *It exists in water, and all fluids used by men and animals* for drink or diluents.

---

* Pilatre de Rozier was accustomed, not only to fill his lungs with hydrogen gas, but to set fire to it as it issued from his mouth, where it formed a very curious jet of flame. He also mixed pure hydrogen gas with one ninth of common air, and respired the mixture as usual; "but when he attempted to set it on fire, the consequence was an explosion so dreadful, that he imagined his teeth were all blown out."

(*c.*) *It is a constituent of all animal and vegetable bodies*, and is found in almost every part of them.

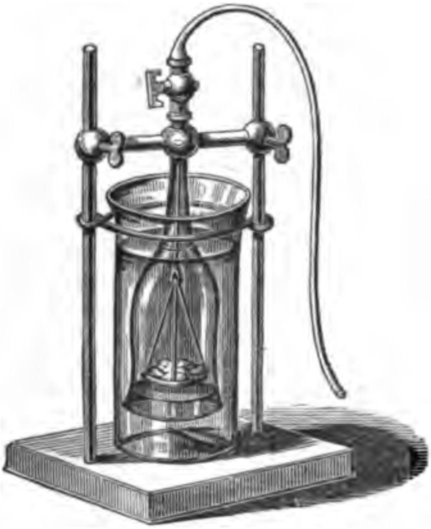
(*d.*) It exists in mineral coal of every variety, and most abundantly in the bituminous coal.

9. *Its combining weight*, when it is made unity for other bodies, is of course expressed by 1; if oxygen be unity, then hydrogen will be .125. These are Dr. Thomson's numbers, but I have already stated the reasons why I prefer making hydrogen unity, as most writers now do.

10. Polarity.

Hydrogen, in the galvanic circuit, resorts to the negative pole, and is therefore considered as electro-positive.

Self regulating reservoirs, for hydrogen and other gases, are occasionally convenient; the following are from Dr. Hare, being improved upon the original contrivance of Gay Lussac.*

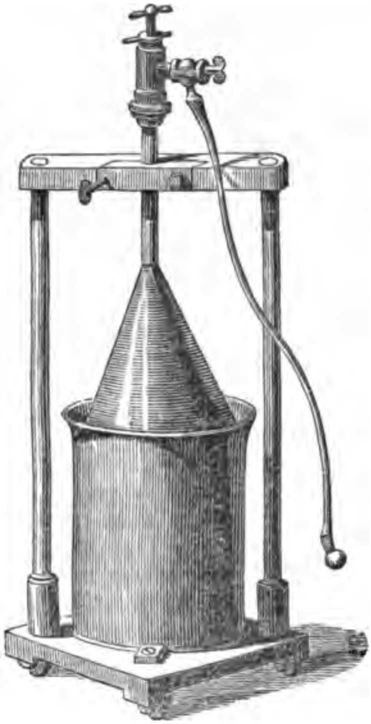


"Suppose the glass jar without, to contain diluted sulphuric acid; the inverted bell, within the jar, to contain some zinc, supported on a tray of copper, suspended by wires, of the same metal, from the neck of the bell. The cock being open, when the bell is lowered into the position in which it is represented, the atmospheric air will escape and the acid, entering the cavity of the bell, will, by aid of the zinc, cause hydrogen gas to be copiously evolved. As soon as the cock is closed, the hydrogen expels the acid from the cavity of the bell; and consequently, its contact with the zinc is prevented, until another portion of the gas is withdrawn. As soon as this is done, the acid re-enters the cavity of the bell, and the evolution of hydrogen is renewed, and continued, until again arrested, as in the first instance, by preventing the escape of the gas, and consequently causing it to displace the acid from the interior of the bell, within which the zinc is suspended."

---

* Dr. Hare states that he used an apparatus of this kind, at Williamsburgh, Va. before he had heard of that of Gay Lussac. It will be seen farther on, that such a contrivance is admirably adapted for obtaining light, instantaneously, by allowing the jet of flame to flow upon spongy platinum.

Large self-regulating reservoir, for Hydrogen.



"This figure represents a self-regulating reservoir, for hydrogen gas; it is constructed like that described in the preceding article, excepting that it is about 50 times larger, and is made of lead instead of glass."

"This reservoir is attached to the compound blowpipe, in order to furnish hydrogen; and may, of course, be used in all experiments, requiring a copious supply of that gas."

On account of the extensive uses of oxygen and hydrogen gases, in a philosophical laboratory, it is highly convenient, to have them always on hand, in large quantities; and, of course, in separate reservoirs, between which there is no possibility of communication.

WATER.—SYNTHESIS.

11. The combustion of hydrogen produces water, and provided the gases be pure,* it produces nothing else.

(*a.*) Burn a jet of hydrogen gas in a tall glass tube, and water, in visible drops, will soon line the tube.

(*b.*) The same may be done in a bottle, filled either with common air, or with oxygen gas.

(*c.*) Or burn a double stream of the two gases, coming from distinct reservoirs, and mingling at the moment of exit.

In these cases the receiver should be kept cold.

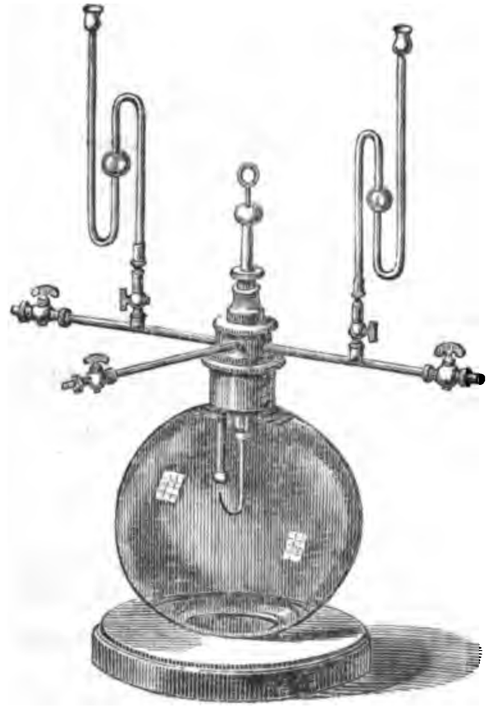
(*d.*) If a bladder, furnished with a stop cock, and a bent tube, be filled with hydrogen gas, and the gas, kindled in a jet, be allowed to burn under a jar of common air, or better of oxygen gas, standing over mercury, there will be a rapid rise of the metal, and water will appear, first in vapor, and then in minute drops, lining the interior of the jar.

---

* Sometimes a little nitric acid or nitric oxide, is formed at the expense of the nitrogen; or carbonic acid, from carburetted hydrogen, these being accidental impurities in the gases.

(*e.*) I find it perfectly easy to fill a large glass globe with oxygen gas, by allowing it to flow from a reservoir through a tube descending to the bottom of the globe, and it is known when the latter is full by applying a taper, blown out, and having a little fire on the wick, which is then rekindled at the mouth of the globe. This arrangement saves air-pump exhaustion. The hydrogen gas is then lighted in a jet, and allowed to flow from a gasometer as long as it is needed. As I employ the compound blow-pipe in this experiment, it is easy to let in either oxygen or hydrogen as it is needed, and thus the combustion is continued at pleasure. The production of water in this mode is immediate and palpable. I subjoin a figure of a beautiful but more complicated apparatus.

Lavoisier's apparatus for the recomposition of water.



"This apparatus consists of a glass globe, with a neck cemented into a brass cap, from which three tubes proceed, severally communicating with an air pump, and with reservoirs of oxygen and hydrogen. It has also an isulated wire, for producing the inflammation of a jet of hydrogen, by means of an electric spark. In order to put the apparatus into operation, the globe must be exhausted of air, and then supplied with oxygen to a certain extent. In the next place, hydrogen is to be allowed to enter it in a jet, which is to be inflamed by an electric spark. As the oxygen is consumed, more is to be admitted."

"I have employed a wire ignited by galvanism, to inflame the hydrogen in this apparatus, and conceive it to be a much less precarious method than that of employing an electric machine, or electrophorus."—*Hare.*

(*f.*) *Oxygen and hydrogen may be combined by explosion.*—This happens of course, in all cases where they are fired together; the product is lost, if the explosion finds vent into the open air, but if confined to an eudiometer tube, over mercury, a little water will be obtained; this is never done except for the purposes of eudiometry, which will be mentioned again.

(*g.*) *Oxygen and hydrogen combine by pressure.*—The two gases, will remain forever in mere mixture, at the common temperature and pressure, without combining; but by sudden and violent compression in a syringe, they will explode, probably on account of the heat which is thus evolved, for "an equal degree of condensation, slowly produced, has not the same effect."

These gases combine slowly above the temperature of boiling mercury, and below that of glass when ignited, so as to be just visible in the dark.

12. PROPORTION OF THE ELEMENTS.

(*a.*) By volume, 2 hydrogen, and 1 oxygen,

$$\left.\begin{array}{l}\text{by weight, 88.9 oxygen,}\\ \text{" \ " \ 11.1 hydrogen,}\end{array}\right\}\text{ very nearly.}$$

The combining weight, if there be one proportion of each,

$$\left.\begin{array}{lr}\text{will be, oxygen,} & 8\\ \text{" \ " hydrogen,} & \underline{1}\end{array}\right\}\text{ or in decimal ratio, }\left\{\begin{array}{r}10.00\\ \underline{1.25}\end{array}\right.$$

Combining weight of water, 9* or 11.25

(*b.*) The proportions of the elements in water, have been settled after the most rigorous and often repeated analysis. The atomic hypothesis, and the theory of definite and multiple proportions, are built upon the result of this analysis. All chemists take either oxygen or hydrogen for unity, and of late the weight of opinion and authority is evidently in favor of hydrogen.

WATER—ANALYSIS.

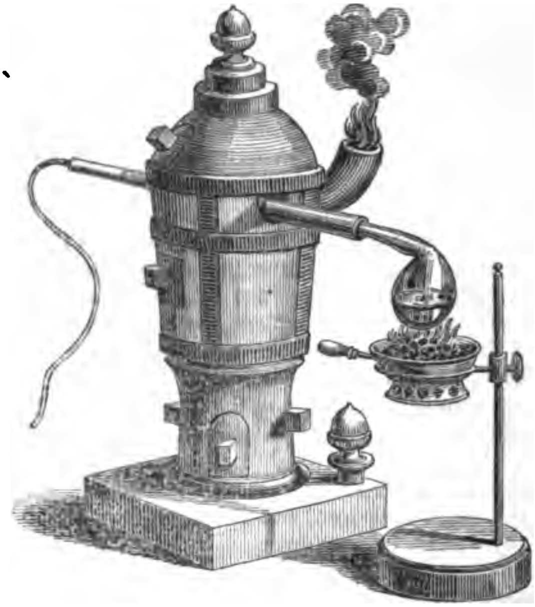
1. If water, in the state of steam, be passed over clean ignited iron, in an iron, or in a luted glass or earthen tube, the iron absorbs the oxygen, and hydrogen gas is obtained; the weight of the hydrogen added to the increased weight of the iron equals that of the water decomposed. Zinc, antimony, and several other metals will answer the same purpose more or less perfectly.

The common arrangement for decomposing water is represented by the following figure from Dr. Hare.

---

* 9 is the number now generally adopted.

Steam decomposed by ignited iron.



" Having introduced some turnings of iron or refuse card teeth, into a clean musket-barrel; lute into one end of the barrel, the beak of a half pint glass retort, about half full of water. To the other end of the barrel, lute a flexible leaden tube. Lift the cover off the furnace, and place the barrel across it, so that the part containing the iron turnings, may be exposed to the greatest heat. Throw into the furnace, a mixture of charcoal, and live coals; the barrel will soon become white hot. In the interim, by means of a chauffer of coals, the water being heated to ebullition, the steam is made to pass through the barrel in contact with the heated iron turnings."

" Under these circumstances, the oxygen of the water unites with the iron, and the hydrogen escapes in the gaseous state through the flexible tube." For 1 grain of hydrogen evolved, the iron gains 8 grs.

2. *Galvanism with gold or platina wires, gives an elegant result;* the two gases, in exact proportion, being obtained in mixture, if the two wires are in the same tube; if in different tubes communicating by a fluid or a wet fibrous solid, then the oxygen will be in one tube and the hydrogen in the other. If the wire is oxidable, hydrogen gas alone is obtained while the wire is in the meantime oxidized.

3. Water is readily decomposed by ignited carbon, but the results are more complicated; carbonic acid gas, carbonic oxide, and carburetted hydrogen gases being obtained.

* * * * *

In this account of the composition of water, as a matter of convenience, the synthesis has been given before the analysis, while the reverse order would have seemed more natural. The synthesis was, however, first discovered, although in every instance of obtaining hydrogen for the experiment, it must have been preceded by an actual, although unknown analysis of water.

In 1776, Macquer and De la Fond, at Paris, burned a jet of hydrogen, and observed that drops of water were condensed from it on a white China saucer, which was not soiled, and in the following year, a similar experiment was made by Bucquet and Lavoisier, who could not satisfy themselves as to what was produced, but ascertained that it was not carbonic acid.

In the spring of 1781, Mr. Warltire and Dr. Priestley fired the mixed gases, but the water produced was supposed to be accidental, or to have been merely deposited from a state of suspension.

In the summer of the same year, and afterwards, more particularly in 1783, Mr. Cavendish burned hydrogen on a large scale, and proved that the product was water; an opinion which had been before entertained by Mr. Watt, and communicated to Dr. Priestley and to De Luc. Mr. Cavendish, without any knowledge of Mr. Watt's opinion, had drawn the same conclusion, and is therefore the discoverer of the composition of water. Among the innumerable experiments which have confirmed this result, that made by Fourcroy and his companions, is worthy of particular commemoration; the gases were kept burning more than a week, 37500 cubic inches were consumed, and fifteen ounces of pure water were obtained precisely equal in weight to that of the gases employed.

The decomposition of water was first effected, understandingly, by Lavoisier, in 1783, by passing the steam of water over ignited iron; the increase of weight in which, added to the weight of the hydrogen gas obtained, precisely equalled that of the water decomposed. The iron is found to be in the same condition as if it had been burned in oxygen gas or common air, it being a protoxide.

WATER.—ITS PROPERTIES.

1. *It absorbs spontaneously, a small quantity of air*, which escapes by the action of the air pump, or by boiling, and in the Torricellian vacuum. Water absorbs oxygen, rather than nitrogen from the air; water that has been exposed to the air, contains over 31 per cent. of oxygen; this fits water to support the life of fishes, and gives it pungency and vivacity to the taste. The air obtained by ebullition from rain water, contains 32 per cent. of oxygen; that from snow water 34.8, but if the atmosphere be excluded during its melting, it is nearly free from air; this is not contradictory, for during the freezing of water, the air is expelled, and is again absorbed when it melts. When

water absorbs any other gas, the air which it contains is more or less expelled; hence, gases confined over water, are soon contaminated in this manner. In boiling water, the first portions expelled contain the most oxygen; the nitrogen comes more tardily, and, if after boiling and air pump exhaustion have ceased to evolve any more gas, electrical discharges be passed through water, more nitrogen will be evolved along with oxygen and hydrogen, proceeding from the decomposition of the water.

2. *Boiled water, absorbs a portion of every gas.*[*]—The quantity absorbed is increased by pressure and by cold, and the facts will be more particularly stated in giving the history of each particular gas.

3. *Water always exists in the atmosphere, in the driest weather.*

(*a*.) Deliquescent substances attract it, as potash, sulphuric acid, and muriate of lime.

(*b*.) Cold bodies condense it, in dew or hoar frost.

(*c*.) *Porous bodies absorb water from the air.*—Dry earth, dry oat meal, and dry metallic filings, afford examples.

4. *Water, by combination becomes solid.*—This is seen in the hydrated alkalies, potash and soda, in the hydrated oxides, and in many crystals, especially artificial ones; when crystals contain water, it is always in definite quantity.

5. *Water, dissolves a great variety of bodies*, more, probably, than any other fluid—acids, alkalies, salts, gum, sugar, alcohol, &c.

It is the most general solvent to bring substances together, under such circumstances as to promote the various chemical processes of nature, and as it alters their properties very little, it is favorable to chemical action by bringing many solids into a state of fluidity. But in some cases, its chemical action is highly important.

6. *The solution of a solid in water generally produces cold.*—Bi-carbonate of potash and caustic potash crystallized, produce cold; but caustic potash that has been recently ignited, or which after that operation has not again absorbed water, dissolves with a rise of temperature.

7. *Air is disengaged during the solution of bodies in water.*—It is partly contained in the crevices of the bodies, and partly dissolved in the water.

8. Water, when pure, is perfectly transparent, tasteless, colorless, and inodorous. According to Professor Robinson, a cubic foot of water at the temperature of 55°, weighs 998.74[†] oz. Avoirdupois, or 62.42 lbs. A cubic inch at 60°, and at 30 inches pressure, weighs 252.525 grains. Pure or distilled water, at the temperature of 60°, is always taken as the unit, when we speak of the specific gravity of other bodies.

---

[*] See a table, Henry, Vol. I, p. 225.

[†] In round numbers 1000.

The refractive power of water is very high, owing, as is supposed, to the hydrogen which it contains. By a vigorous stroke in a syringe, water emits a flash of light.—*Thenard.*

Water has generally been regarded as incompressible, but Mr. Perkins applied to it a force of 2000 atmospheres, and stated the compression at $\frac{1}{13}$, but Prof. Oersted* justly considers this estimate as far too great. It would appear from a note by the late Prof. Fisher,† of Yale College, that the subject is not quite new, and Mr. Canton, so far back as 1764, ascertained that water expands $\frac{1}{21740}$ part, by the removal of the pressure of the atmosphere, and that an additional atmosphere reduces its volume in an equal degree. No natural water is quite pure; it always holds saline and earthy matters dissolved besides gases; rain or snow water obtained away from population, as on a mountain, is the purest. It is obtained pure by distillation, especially in vessels of gold, silver, or platinum. Distilled water is indispensable in all accurate chemical operations.

8. *Utility of water.*—It is far more abundant than all other fluids; it is indispensable to animal and vegetable life, and no other fluid would answer the same purposes.

Water enters into the composition of all the solids and fluids which we consume for food and drink; it imparts that humidity to the air which in breathing moderates animal heat; it affords by its pressure and motion, the means of great mechanical operations, and it facilitates commerce and friendly communication between nations. It is necessary that its properties should be negative, or it would be injurious.

Gazometer for oxygen or any gas not absorbed by water.—Dr. Hare.

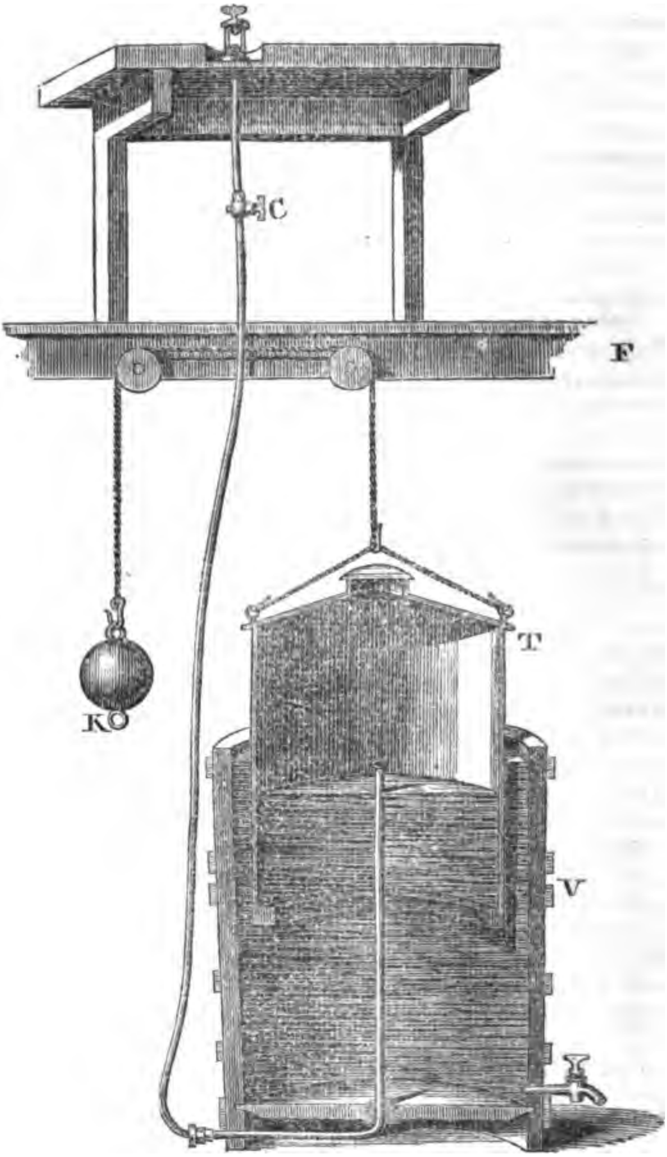
"The engraving on p. 214, represents a section of the gazometer for oxygen, which is capable of holding between five and six cubic feet of gas. It is placed in the cellar beneath the lecture room. The wooden tub, V, is necessarily kept nearly full of water. The cylindrical vessel, T, of tinned iron, is inverted in the tub, and suspended and counterpoised, by the rope and weight, in such manner, as to receive any gas which may proceed from the orifice of the pipe, in its axis. This pipe passing, by means of a water-tight juncture, through the bottom of the tub, rises through the floor, F, is furnished with a cock at C, and terminates in a gallows screw. This is fixed in a cavity made in the plank forming the table of the lecture room, in the vicinity of the pneumatic cistern. Hence by means of it, and a leaden pipe soldered to a brass knob, properly perforated, a communication may be established between the cavity of the gazometer, and any other vessel, for the purpose either of introducing or withdrawing the gas. The counter-weight being made heavier than the vessel, by appending additional weight to the ring, K, the gas may be sucked in from a bell glass, (situated over the pneumatic cistern,) as fast as it enters the bell, from the generating apparatus."

---

* Edin. Jour. No. 12, p. 201.

† Am. Jour. Vol. III, p. 347.

"Gazometers which contain 40 or 50,000 cubic feet, have been constructed upon this principle, for holding the gas from oil or coal."



Deutoxide of Hydrogen.

1. **History.**—Until 1818, water was believed to be the only compound of hydrogen and oxygen; but in that year, Thenard published in the Transactions of the Academy of Sciences of Paris,* an account of this singular substance, and hitherto little has been added to the facts stated in the original memoirs by this celebrated chemist.

2. **Preparation.**†—From the peroxide of barium, by the action of diluted muriatic acid, and then of sulphuric acid, both, a number of times repeated; followed by that of sulphate of silver, and then by

---

* Thenard's Chem. 4th Ed. Vol. V, p. 41.

† The principal steps of this complicated process, which the student will not be expected fully to understand until farther advanced, are as follows:—

1. Prepare nitrate of baryta; this may be done by decomposing the sulphate of barytes by igniting it with charcoal, by which it is turned into a sulphuret; this is decomposed even in an iron vessel by nitric acid, and any iron that is taken up is precipitated by baryta, and the nitrate of baryta is then crystallized.

2. The nitrate is decomposed by ignition in a porcelain retort; (if the heated nitrate be withdrawn from the fire in proper time, it will be left in the state of a fine deutoxide, but*) it is commonly oxygenized by passing the dry pure oxygen gas over the ignited baryta contained in a luted glass tube; the oxygen is rapidly absorbed, and we obtain the deutoxide or peroxide of barium; it is this very portion of oxygen thus absorbed, which is to be transferred to water or rather to its hydrogen, and it is done in the following manner.

3. Take water, six or seven ounces, and strong muriatic acid sufficient to dissolve 280 grains of baryta, and add 185 grains of powdered peroxide of barium; the solution is without effervescence, because, although the acid combines only with the protoxide, the excess of oxygen is not disengaged, but unites to the water or to the hydrogen of the water; the water thus becomes oxygenized, but in too small a proportion to be observed.

4. Sulphuric acid is now added, just enough to precipitate the barytes, and the muriatic acid is thus liberated, and is again ready to act upon more of the peroxide, which, as before, is now added in the proportion of 185 grains; this is dissolved; the excess of oxygen is added to the water; the barytes is again precipitated by sulphuric acid, and the insoluble sulphate is separated by the filter; thus the process is repeated a sufficient number of times, until about three ounces of the peroxide have been employed, when the liquid will contain from twenty five to thirty times its volume of oxygen gas.

5. The solution is now a mixture of muriate of baryta with oxygenized water, and to remove the salt, its acid is first separated by sulphate of silver, which forms muriate of silver, and liberates the sulphuric acid, which, in its turn, is removed by solid baryta in powder and by filtration.

6. The solution is now the oxygenized water, or, as it is more properly called, the peroxide of hydrogen, but still containing more water than is necessary for its solution; this is removed by the air pump; the vessel containing the peroxide of hydrogen is placed in another about two thirds full of sulphuric acid, and the vacuum is formed over it, which occasions the evaporation of the water, and leaves eventually nothing but the peroxide, which, if continued in the vacuum, is finally, but very slowly volatilized unchanged. Thenard says, "au bout de deux jours la liqueur contiendra peut-être deux cent cinquante fois son volume d' oxygene." The peroxide, as thus obtained, has the specific gravity of 1.452, and it did not grow any denser by continued exposure to the vacuum, although it diminished considerably in quantity.

Minute as this abridged statement may appear, there are many details necessary to success, for which recourse must be had to Thenard's own account in his Chemistry, or in the Ann. de Chim. et de Phys. Vols. VIII, IX and X; or Ann. of Phil. Vols. XIII and XIV.

* The clause in parenthesis communicated by Dr. J. Torrey.

baryta, and finally by concentration by air pump exhaustion, aided by the affinity of the vapor of water for sulphuric acid.

3. PROPERTIES.

(*a.*) *They are remarkably different from those of water.*—The fluid is colorless and inodorous; destroys gradually the color of litmus and turmeric paper;* is somewhat corrosive to the skin, bleaches it, and if abundantly applied, destroys it. It bleaches the tongue, makes it tingle, and gives a peculiar taste resembling that of metallic solutions.

(*b.*) *Although much more fixed than water, it may be entirely evaporated in a vacuum,* without decomposition. At 59° Fahr. it is decomposed into water and oxygen gas. It can therefore be scarcely preserved except surrounded by ice; but it remained fluid at every degree of cold applied to it.

(*c.*) *At 212°, it is decomposed explosively,* oxygen gas being liberated, and therefore if we would decompose it by heat, it must be previously diluted. Diffuse day light has no effect upon it, and direct solar light very little.

(*d.*) *It is decomposed by nearly all the metals, and by most of their oxides,* these substances being in a state of minute division.

(*e.*) *Those that powerfully attract oxygen combine with a portion of it;* such are potassium, sodium, arsenic, zinc, &c. and in this way several metallic protoxides become peroxides, and on the same principle hydriodic acid, sulphurous acid and sulphuretted hydrogen, attract oxygen from this fluid and bring it to the condition of water.

(*f.*) *Oxide of silver*† *decomposes the oxygenized water with explosion.*—This happens if the fluid falls on the silver, drop by drop, and if the place be dark, light is seen.

(*g.*) *Several other peroxides decompose this oxygenized compound.*—Such are those of manganese, cobalt, lead, platinum, gold, iridium, rhodium, and palladium; the oxygen of the water is always disengaged, and sometimes that of the oxide. The decomposition is complete and instantaneous, and sometimes ignition is produced in the glass tube containing the materials.

---

* Some have supposed that the bleaching powers of chlorine may depend on the mixture with it, of a small quantity of oxygenized water.

† In the Am. Jour. Vol. XVII, p. 84, Dr. Ed. W. Faust has suggested, that this curious phenomenon of the decomposition of oxygenized water by oxide of silver, may be accounted for upon galvanic principles: thus

"When any metal is placed in the peroxide of hydrogen, a galvanic effect is produced. The hydrogen having less affinity for the *excess* of oxygen, than the metal has, the liquid becomes negative, thus acting the part of the copper plate of a battery, while the metal becomes positive, supplying the place of the zinc plate. The liquid is thus resolved into water and oxygen. If the metal be very oxydable, it retains the oxygen, which is evolved if gold, platina, &c. be used. We need scarcely refer to the wires of a battery, for a parallel case.

"When the peroxide of hydrogen comes in contact with the oxide of silver, the oxygen escapes from both, and the latter is reduced to the metallic state." For a fuller account, see the paper of Dr. Faust.

(*h.*) *Water and acids, especially the more powerful, render the compound more permanent:* if the liquid has begun to effervesce by heat, a drop of the stronger acids, and even of the principal vegetable acids, will cause it to cease, and the addition of an alkali will cause the effect to be renewed.

(*i.*) *Peroxide of hydrogen is decomposed by heating carefully the diluted solution:* its composition as ascertained by its discoverer, Thenard, is hydrogen 1 proportion and oxygen 2 = 16, and 17 is therefore its representative number. From its great specific gravity, it sinks in common water as sulphuric acid does, although it has a great affinity for that fluid.

Thenard suggested an application of it to remove dark spots from pictures, in which white lead paint had become tarnished by sulphuretted hydrogen: this it effected instantly by the agency of the oxygen of the oxygenized water, which converted the sulphuret into a sulphate.

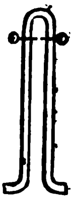
Many other particulars might be added respecting this curious compound, but they would be inconsistent with the extent of this work. There does not appear any positive proof that the combination of the oxygen is with the hydrogen directly, rather than with the entire water, but the fact that the oxygen bears a multiple relation to that contained in water, affords a strong presumptive proof; perhaps a satisfactory one, in support of the former view.

EUDIOMETRY BY HYDROGEN.

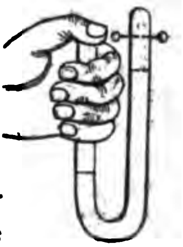
Eudiometry has been already mentioned in giving the history of the atmosphere, and it remains to describe, as fast as we come to them, the action of the various substances that operate to remove oxygen from the air, or from any mixture of gases. Hydrogen is one of the most effectual.

1. *Modes of application.*

(*a.*) *In a common eudiometer tube.*—This kind of tube is made very stout, as in the annexed figure: the glass is well annealed, its mouth is usually trumpet shaped, it is graduated and furnished, towards the top, with two wires, cemented into the glass, and approaching, but not touching each other. In this manner, an electric spark is easily made to pass through the mixed oxygen and hydrogen gases, and an explosion and diminution of volume follow.



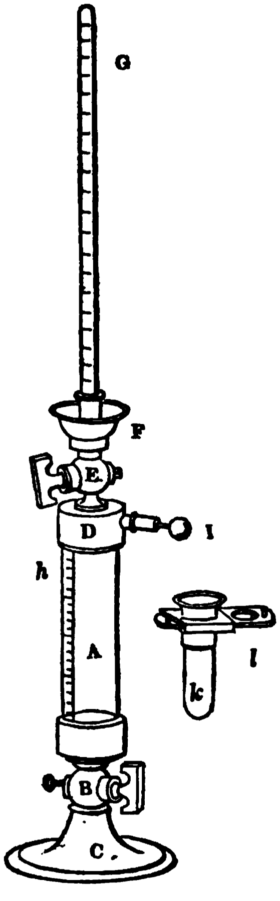
(*b.*) *Dr. Ure's eudiometer,* of which a figure is annexed, is very simple. It is a syphon tube, closed at one end, and with platinum wires hermetically inserted: it is of course graduated: its legs are both from six to nine inches long, and the interior diameter is from two to four tenths of an inch: it will receive safely one fourth of an inch of the mixed oxygen and hydrogen gases, and nearly an equal volume of olefiant gas mixture: the water or mercury in the



bend is brought to the same level, and two inches or more of air is left in the leg, which is held in the hand. The thumb is pressed firmly upon the orifice, and the spark taken either through the hand as a part of the conducting substance, or by a wire: the elastic spring of the confined air prevents all danger of explosion, only a very slight pressure being felt at the moment.*

(*c.*) *Volta's eudiometer.*—I give, from Dr. Hare, a figure of this elegant, but expensive, and rather complicated instrument, which is now little used, and I therefore omit the detailed description, which may be found in Dr. Hare's Compendium.

A and G are graduated glass tubes: each division of the 200 parts of A corresponding to 10 of G, which holds 10 measures of A. C is a funnel-shaped foot, with a stop cock and cap for introducing gas from the measure, *k*, which is furnished with a slide so as to give always the same measure. I is an insulated electrical conductor. F, a basin shaped cap for pouring in water, and to admit of introducing G, air tight, with a finger on the orifice, so that (F being filled with water,) it may be screwed to its place, or removed from it without loss of its contents. There is of course a communication through B and E, and the whole apparatus having been first filled with water, the mixed gases are introduced; the spark taken; B opened under water to ascertain the diminution, and the residual gas being let up into G is there accurately measured.



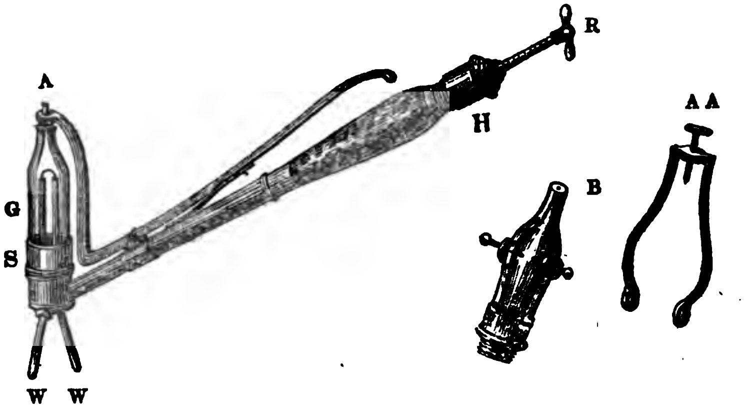
(*d.*) *Dr. Hare's eudiometer.*—To produce the explosion of the gases, this gentleman has availed himself of the ignition produced by a small calorimotor, in a slender platinum wire, forming a part of the connexion in the interior of the eudiometer tubes: he measures the gas conveniently and accurately, by a graduated rod, sliding air tight in the instrument, and also by some separate instruments called volumeters, and sliding rod gas measures. To one of his eudiometers a barometer gage is attached, by which the amount of absorption is accurately ascertained. The ignition of the platinum by the calorimotor, for the purpose of inflaming the gases, is an elegant and novel method of operating; the various modes of measuring the gases are ingenious and accurate, and the detailed description of all the instruments and operations may be found in Dr. Hare's Compendium, and in the Am. Journal.

---

* For a more detailed description, see Ure's Dictionary, art. Eudiometer; also Edin. Phil. Trans. Jan. 1818.

We subjoin the figure, and an abridged description of the simplest of these eudiometers.

Hydro-oxygen Eudiometer of Dr. Hare.



W W Two brass wires passing through the socket S, and appearing within the glass detonating tube G, where they are connected at the top by a soldered arc of platina wire, visible in the drawing. One of the brass wires is soldered to the socket. The other is fastened by means of a collar of leathers, packed by a screw, so that it has no metallic communication with the other wire, unless through the filament of platinum, which is called the igniting wire.

At A is a capillary orifice in the glass tube, which is opened and closed by the lever and spring, seen in the drawing, and it may be guarded by a gallows screw, in the iron staple A A, which may be appended to the instrument by pivots at S, and the opposite point, and may be dropped out of the way when the eudiometer is to be charged.

R The sliding rod, is acurately graduated to about 160°, and to diminish the chance of leakage, a stop cock may be interposed between the sliding rod and the detonating tube.

B represents a detonating tube, to be discharged by an electric spark; it may be screwed into the socket S, instead of the tube G.

The sliding rod eudiometer being ascertained to be tight, is filled with water, free from air bubbles, the rod being introduced to its hilt, and the valve at A being open, the rod is drawn out and the instrument being in the atmosphere, common air of course enters, or the eudiometer is placed under a bell glass, and the gases, either successively, or previously mixed in the proper proportions, are then introduced by suction of the graduated rod A, and the wires W W being applied to the two poles of a calorimotor, at the moment in action, the explosion takes place. The valve being opened under water, this fluid enters to supply the place of the gases consumed, and any residuary air being excluded by the sliding rod, the portion of the latter remaining without, will, by the graduation, indicate the deficit, which is to be apportioned by the rules given below; that is, $\frac{2}{3}$ of the diminution is hydrogen, and $\frac{1}{3}$ is oxygen.*

For the purpose of the general student, any mode in which the mixed gases can be exploded conveniently and the diminution easily ascertained, will answer every valuable purpose.

USE OF THE HYDRO-OXYGEN EUDIOMETER.

If we mix accurately 2 volumes of hydrogen with 1 of oxygen, and inflame them in any of the above named eudiometers, provided the gases are pure, there will be a total condensation.

As it is however rare that the gases are quite pure, it is often best to employ an excess of that gas which is used to detect the other. In examining oxygen gas, if we take three volumes of hydrogen, one third of the diminution being oxygen, it will not injure the result, if there should be a residuum. If 100 measures of oxygen gas are fired with 300 hydrogen, and there is a residuum of 130, it follows that 270 have disappeared, and 90 is one third of this, and of course it appears that there is 10 per cent. of foreign gas, it may be nitrogen, or carbonic acid; for there is an excess of 100 of hydrogen.

Suppose, on the other hand, that we fire equal measures of oxygen and hydrogen, say 100 of each; if the 200 are reduced to 80, the diminution will have been 120, and two thirds of this, that is 80, is owing to hydrogen; it follows of course, that there is in the hydrogen 20 per cent of foreign gas most probably nitrogen.—*Henry.*

If 100 measures of common air are mingled with 50 of hydrogen, and exploded, the 50 volumes will generally be reduced to 87, giving a diminution of 63 measures, one third of which, 21, is the proportion of oxygen usually assigned to the atmosphere.

---

* The figure of the calorimotor used in these experiments will be given under the head of Galvanism. For a more detailed account, and various particulars to insure accuracy, see Dr. Hare's Compendium.

Not being in possession of the wood cuts of the barometer gage eudiometer, and of the sliding rod gas measure, I have been obliged to omit an account of those instruments which I had prepared.

Dr. Thomson (First Principles,) employed 42 volumes of hydrogen to 100 of air, and always obtained a reduction of 60, one third of which, 20, corresponds with the theory of volumes, and also of multiple proportions by weight, and granting that atmospherical air is a feeble compound, this would appear to be, in all probability, the true proportion; and if this is the true proportion, this fact in its turn strengthens very much the opinion that in the atmosphere, the elements are not merely mixed, but slightly combined.

The electric spark will no longer cause explosion in the mixture of 2 volumes of common air, and 1 of hydrogen gas, when there are 12 parts of common air, or 9 of hydrogen added to the mixture, or when it is rarefied 16 times by diminution of pressure, or 6 times by heat. Oxygen and hydrogen gases, in the proportion to form water, if rarefied mechanically 18 times, will not explode by electricity; according to Sir H. Davy, rarefaction by heat causes the mixed gases to explode more readily by the temperature of ignition.

In the analysis of atmospheric air by hydrogen gas, 5 volumes of air should be sufficient for 2 of hydrogen; but it is better to employ a small excess; here, as before, one third of the diminution will be owing to oxygen. Dr. Hare says, that in a great number of experiments, performed by means of his instruments, he obtained very constantly 20.66 as the quantity of oxygen in 100 parts of the air, and that in twenty experiments, the greatest discordance did not amount to $\frac{1}{100}$ in 100 measures of air.—*Comp.*

ACTION OF PLATINUM.

(*a.*) A very effectual eudiometer was unexpectedly presented to us by a discovery of Dobereiner, of Jena. The muriate of platinum and ammonia, when ignited, leaves the metal in the state of spongy platinum,* upon which, if a stream of hydrogen be directed, the metal, if air has access, becomes ignited, and the gas soon takes fire.

(*b.*) It is necessary that the oxygen gas of the air be let in at the same time, and water is the result, as if the gases had been kindled in any other way.

(*c.*) If spongy platinum be introduced into a mixture of oxygen, or common air, with hydrogen gas, in explosive proportions, they detonate; in other proportions they slowly combine and form water.

(*d.*) The spongy platinum being formed into a paste, with about an equal weight of alumine, or china clay, and water, with the addition of some muriate of ammonia, to preserve the porosity, and made into balls of the size of peas, and dried, at first slowly, and afterwards more rapidly, the balls will act in the same manner as the sponge, and their power is renewed by heating them in the blowpipe flame; being thus treated, they will, if preserved from dust, answer a thousand times, and more; their size need not be over 2, 4, or 6 grains. If one of the balls, fastened for convenience, to a piece of platinum wire, be introduced into a mixture of air 100, and hydrogen gas 50 measures, it will in a few minutes be reduced to 87; the diminution, 63, divided by 3=21, the proportion of oxygen.

---

* Or the sub-oxide of platinum, prepared by Mr. E. Davy's process, answers, perhaps equally well.

† See Henry, Vol. I. p. 238, and Ann. de Chimie et de Phys. 23, and 24.

(*f.*) In general, the platinum at common temperatures does not act upon the gases that are found mixed with hydrogen; but if the ball is hot, it sometimes acts upon the residuary nitrogen to form ammonia, and produces a diminution greater than 63.

(*g.*) Moist platinum sponge has the same power as dry, only it requires a longer time. If some of the ammonio-muriate of platinum be ignited in the sealed end of a glass tube, or if its solution be decomposed there, by a rod of zinc, a thin film of the metal will adhere firmly to the interior of the tube. In such a tube, a mixture of oxygen and hydrogen, or of the latter and common air, will be decomposed in a few hours: and if the hydrogen prevail, all the oxygen will disappear; in this manner hydrogen can be perfectly purified from oxygen; even one part in 100 will be abstracted, which much exceeds the power of hydrogen alone, aided by the electric spark.

(*h.*) Dobereiner supposed this to be a peculiar galvanic arrangement, in which the hydrogen represents the zinc, and the platinum the copper; but it appears that no heat is produced, unless oxygen or atmospheric air is present; so that the office of the metal appears to be to produce a combustion of the hydrogen.

(*i.*) Platinum, in fine powder, produces no action, not even a slow one; the laminated metal and its wire are equally inert, but thicker leaves and wire acted, although slowly, when heated to between 200° and 300°, Centigrade. A very thin film of platinum, rolled round a glass tube, or suspended freely in a detonating mixture, produced no effect in several days; but when crumpled like the wadding of a gun, it produced instant detonation.

(*j.*) Platinum sponge strongly ignited, loses the property of becoming incandescent; but produces slowly, and almost imperceptibly, the combination of the two gases.

(*k.*) This phenomenon appears still more remarkable, when it is considered that it happens between the lightest and the heaviest body known.

(*l.*) If, upon a mixture of spongy platinum, and nitrate of platinum, and ammonia, a jet of hydrogen be directed, the mixture reddens, crackles, and emits inflamed sparks.

(*m.*) Alcohol is turned into acetic acid and water, by the action of the sulphuretted oxide of platinum;* the same effect is produced by the black powder which zinc precipitates from the platinum solution.

(*n.*) Several metals act in a similar manner upon mixtures of oxygen and hydrogen; among them, palladium is the most effectual; this metal, and iridium inflamed the mixed gases at common temperatures, and gold and silver acted efficiently at a heat below 212°.

Modes of preparing Platinum sponge.

(*a.*) According to my own experience, when common crude grain platinum is dissolved in nitro-muriatic acid, and precipitated by muriate of ammonia; this orange precipitate being collected by subsidence, may be partially dried in a Wedgwood's or other dish, and then transferred into a platinum crucible, which may be gradually heated in a little earthen furnace, till the fumes of muriate of ammonia cease to appear. The cover of the crucible may now be put on, and the whole buried in burning coals, which may be blown by hand bellows, both above and below, until it is fully ignited; it need remain in this state not more than two or three minutes, when it may be withdrawn and cooled.

(*b.*) The orange precipitate may be thrown upon a filter, the filter dried, and introduced directly into the crucible. A greater division of the platinum takes place in consequence of the mixture with the carbon of the burnt paper, and causes the platinum to ignite more readily in a jet of hydrogen; neither is there any waste of the precipitate.†

(*c.*) If a stream of hydrogen from the compound blowpipe, or other jet, fall upon the sponge, it will be ignited, and the hydrogen will take fire.‡

(*d.*) If the oxygen be let in at the same time, or immediately after, the mixed gases are instantly lighted with a slight explosion.

---

* Procured by precipitating the muriate of platinum by sulphuretted hydrogen.

† The above circumstance was observed in the laboratory of Yale College, by Mr. C. U. Shepard, and noted Feb. 17, 1827. In the Journal of the Royal Institution, for April, 1829, it is mentioned that Mr. Pleischel recommends that a piece of paper be three times immersed in the solution of muriate of platinum, and then burnt, which leaves the platinum in the best state for producing ignition. The Editors of the Journal say, that a little of the ammonio-muriate of platinum being heated upon platinum foil, in a spirit lamp, with the mildest heat that will dissipate every thing volatile, the platinum will be left in a fit state to inflame a mixture of oxygen and hydrogen, at the lowest possible temperature.

Dr. Webster recommends dipping a cotton cloth in the solution of the muriate of platinum, and then burning it to tinder, which, if kept dry, will ignite as readily as the sponge.

‡ This contrivance is so good a substitute for the complicated, although elegant instrument of Volta, in which a jet of hydrogen is fired by a spark from an electrophorus, that I have not thought it best to give a drawing and description of this instrument, both of which may be seen in Dr. Hare's Compendium, p. 65.

(*e.*) These facts are best exhibited in public, by placing the platinum in a wine glass, but as it is liable to break from the sudden heat, it is well to place a dish beneath.

(*f.*) After precipitation of the orange precipitate, the yellow supernatant fluid still contains platinum, as is indicated by muriate of tin and hydriodic acid—on evaporation, a solid is obtained, consisting principally of the muriate of ammonia, and probably the foreign metals; for on heating this residuum in a platinum crucible, as in the case of the sponge, a little metallic matter is obtained, which, however, does not ignite the hydrogen.

HARE'S COMPOUND OR OXY-HYDROGEN BLOWPIPE.

1. Dr. ROBERT HARE, of Philadelphia, invented this instrument in 1801; and in December of that year, the discovery was communicated to the chemical society of that city; in 1802, an account of it was published in a pamphlet.* It was used by Dr. Hare and the author of this work, in 1802—3, and full accounts of their experiments were published in the Phil. Trans. of Philadelphia, Vol. VI. In Dec. 1811, an extensive series of experiments was performed by the author, and published in 1812, in Dr. Bruce's Journal, several years before Dr. Clarke's experiments were performed.†

2. Dr. Hare is entitled exclusively to the merit of the discovery. The contrivance of mixing the gases before hand in explosive proportions, is all that has been added, and this is not an improvement; it introduces a serious danger where there was none before, and as regards the heat produced, is attended with no important advantage.

3. The principle of Dr. Hare's instrument is, that the oxygen and hydrogen gases coming from distinct reservoirs, mingle at the moment of their exit from a capillary orifice, and are there ignited with perfect safety.

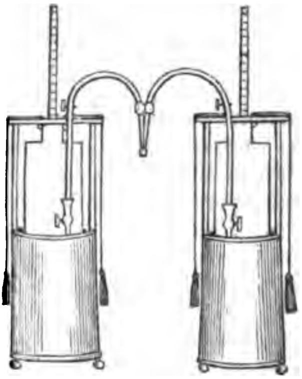
4. Dr. Hare first ascertained, that oxygen and hydrogen gases can be made to burn together in this manner; that the heat thus evolved, surpasses that produced by any other mode of combustion, and that it is scarcely exceeded even by that produced by Voltaic electricity; this might perhaps have been anticipated from the great capacity of the gases, especially of hydrogen for heat.‡

---

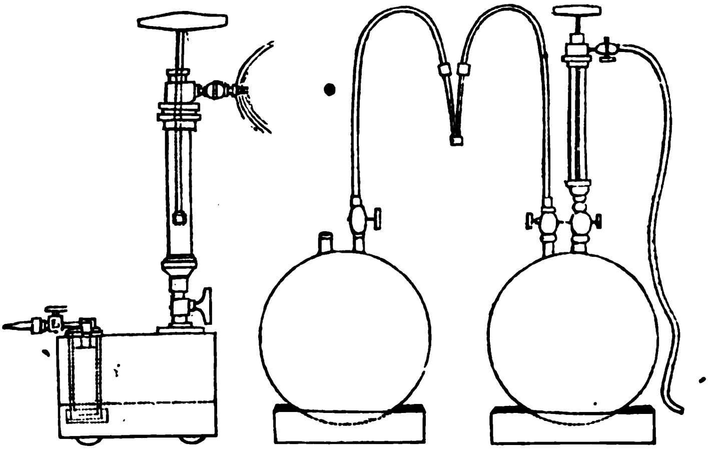
* Which was republished in Vol. XIV, of Tilloch's Phil. Mag. Lond. and in Vol. XLV, of the Ann. de Chim. Paris.

† See Am. Jour. Vol. I, p. 98, and Vol. II, p. 181.

‡ Being an independent original witness to the early use, (in 1802,) of this fine instrument by its inventor; and having been in the habit of using it frequently, for several years before Dr. Clarke's experiments were published, as well as ever since; I embrace this opportunity to say, that no other name, than that of Dr. HARE, can be, in my view, rightfully associated with the invention of the Compound Blowpipe.



5. The apparatus which I employ, is that represented in the annexed figure, the parts of which are described at page 184; it is convenient and effectual, and has, for many years, enabled me to perform all these interesting experiments with great facility, and on a large scale. By adverting to the strictures of Dr. Hare,* and to the statement of the editors of the Annales de Chimie et de Physique,† it will be apparent, that in point of effect, no advantage is gained by mingling the gases, previously to their combustion,‡ and a serious danger is necessarily encountered, notwithstanding the wire gauze, and oil, and mercury valves that have been interposed in the apparatus of Newman or Brooke, whose figure is annexed.§



It is a small copper box, (here represented on the left of the page,) furnished with an injecting syringe, for the introduction of the gases, previously mingled in the proportions to form water; it is furnished also with an internal valvular apparatus of wire gauze, to guard against explosions,* and with a tube of efflux mounted with a stop cock and a platinum orifice. Great pressure may be a convenient means of bringing more of the gases into the reservoir, but it is of no avail as regards the heat, for not being at their efflux, adequately resisted by the air, it amounts to nothing more than supplying the gases in sufficient quantity. The previous accurate adjustment of the proportions, may at first view seem to be a point of importance, but after a little experience, there is no practical difficulty in hitting this proportion, when the gases come from different reservoirs; the eye will easily perceive, by the color and size of the flame, and the appearance of the focal point, when the proper proportion is attained; and the effects have proved that there is no important difference in the power of the instruments. Mr. Brooke's blowpipe has the advantage in neatness and convenience of size, but its contents being soon exhausted must be frequently renewed. It is obvious that the security of Dr. Hare's contrivance may be easily connected with that of Mr. Brooke, by simply providing two condensing boxes of proper size, one for hydrogen and the other for oxygen, and connecting them in the manner represented in the cut on page 225. On account, both of strength and capacity, two globes of metal would be most convenient; and an instrument, like that in the figure above referred to, would unite all the most important advantages of the different varieties of apparatus, hitherto constructed for this purpose, and be at the same time, free from their inconveniences, and from the danger attending Mr. Brooke's.

---

* Am. Jour. Vol. II, p. 281. † Ibid, Vol. III, p. 87.

‡ In the apparatus which I employ, stout tubes of cast silver are screwed into a piece of platinum, shaped like the lower frustrum of a pyramid, and this is the part of the instrument where the gases issue; but common brass tubes hard soldered and screwed into a silver frustrum, will answer; care must however be used, that the silver is not melted, which it certainly will be, if allowed to sink into the hole burned into a charcoal support, on which any thing is melting or burning.

§ Professor Griscom was so good as to bring this instrument to Yale College, some years since, and we made a series of experiments with it, but with no results different from those produced by Dr. Hare's blowpipe. In point of pressure, we carried it so far that the copper parallelopiped, was swollen till its sides were convex, but no advantage appeared to be gained by great pressure.

6. The figure in the note below represents the form of the instrument, at present, used by Dr. Hare. It is less simple than those that have been described, but the inventor says, that he has found it equally convenient in use, as the most simple form, " while its parts are peculiarly susceptible of advantageous adjustment."†

---

* On a principle which will be illustrated under the history of the safety lamp, in the section on the carburetted hydrogen gases.

† " B is a brass ball, with a vertical perforation, terminating in a male screw above, and in a female screw below. Another perforation, at right angles to this, causes a communication with the tube, *t*, which enters the ball at right angles. A similar, but smaller brass ball, may be observed above, with perforations similar to those in the larger ball, and a tube, in like manner, entering it laterally. This ball terminates in a male screw below, as well as above. The thread of the lower screw is curved to the left, while that of the screw of the larger ball, which enters the same nut, *n*, is curved to the right. Hence the same motion causes the male screws to approach, or recede from each other, and thus determines the degree of compression given to a cork which is placed between them, in the nut. At S, above the ball, a small screw may be observed, with a milled head. This is connected with a small tube which passes through the cork in the nut, and reaches nearly to the external orifice, *o*, from which the flame is represented as proceeding. This tube is for the

Effects of the compound blowpipe.

1. Every variety of mineral matter has been melted by it, except the diamond; it is evident that this substance and charcoal are exceptions, merely on account of their combustibility.

2. All combustible bodies burn in the focus, not excepting any of the metals: the latter exhibit beautiful phenomena, depending on the color of their oxides and of the flame: platinum, because it is too fixed a substance to form vapor, burns, not with flame but with scintillation.

3. Peculiar facilities are afforded by having two separate reservoirs for the gases.

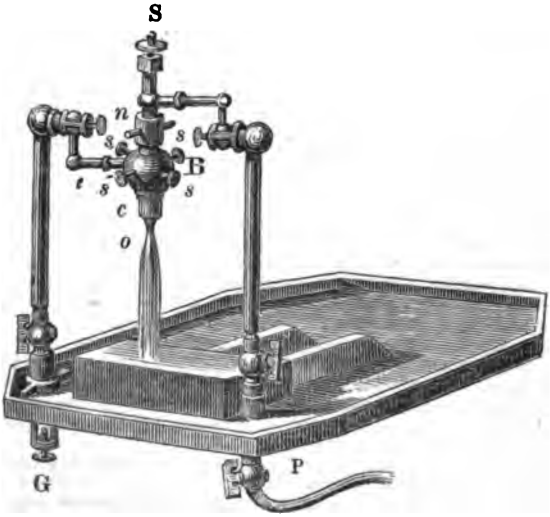
(*a.*) We use the hydrogen flame alone if we wish a lower degree of heat.

---

most part of brass, but at its lower end terminates in a tube of platina. It communicates by lateral apertures with the cavity of the upper ball, but is prevented by the cork, from communicating with the cavity in the other ball. Hence it receives any gas which may be delivered into the upper ball from the lateral pipe which enters that ball, but receives none of the gas which may enter the lower ball, B."

"Into the female screw of the latter, a perforated cylinder of brass, *c*, with a corresponding male screw, is fitted. The perforation in this cylinder, forms a continuation of that in the ball, but narrows below, and ends in a small hollow cylinder of platina, which forms the external orifice of the blowpipe, *o*."

"The screws, *s s s s*, are to keep, in the axis of the larger ball, the tube which passes through it, from the cavity of the smaller ball. The intermediate nut, by compressing, about the tube, the cork which surrounds it, prevents any communication between the cavities in the two balls. By the screw, *s*, in the vertex, the orifice of the central tube may be adjusted to a proper distance from the external orifice.—Three different cylinders, and as many central tubes, with platina orifices of different calibres, were provided, so that the flame might be varied in size, agreeably to the object in view."



(*b.*) We let in a portion of oxygen, more or less, as we wish the heat to be increased to any degree, till we reach the maximum.

(*c.*) We ignite charcoal by the compound flame, and then shut off the hydrogen, if we wish to have the effects of oxygen gas alone.

(*d.*) This is beautifully seen in burning the metals; we first raise the heat by the compound flame, and when the globule of metal is heated very intensely, we cut off the hydrogen and permit the oxygen alone to flow, which at that high temperature sustains, and even increases the combustion of the metals, not excepting cobalt, nickel, silver and gold.

4. Most intense light is exhibited, by bringing incombustible bodies, such as the earths, and particularly lime and argil, in the form of a pipe's stem, or of porcelain, into the focus: the naked eye cannot endure the light: and in this focus the most refractory substances, the rocks, the pure earths and the gems, are melted; the diamond alone excepted, which burns with great intensity, and is soon exhaled in the form of carbonic acid gas.*

THE ALKALIES.

Preliminary Remarks.

Several eminent writers at the present time, have broken up the long established class of alkalies, and distributed them according to relations derived from their composition: ammonia is described in connexion with hydrogen and nitrogen; and potassa, soda and lithia, under the metals. Similar remarks are applicable also to the earths. This course is logical, but it is highly inconvenient; for it is scarcely possible to take more than a few steps in the chemistry of particular bodies, without calling in the aid of the alkalies, in our experiments and reasoning: this remark is perhaps equally true of the principal acids, and both these important classes of bodies should be placed as early as possible in the hands of the student. It has been already stated, in the plan of the work, that in teaching, I have found the most convenience in introducing the alkalies before the acids; although my preference is not so decided that I should have any serious objection to the opposite course. But, I am not willing to postpone the history of the alkalies and earths until we come to that of the metals, and to treat of them merely as appendages of those bodies; and I should be still more reluctant, for the sake of avoiding this difficulty, to bring in the metals first, or in connexion with the simple combustibles, as some authors have done; nor is it a sufficient reason, that the alkalies* and earths then fall in naturally as metallic oxides. It is true that modern discovery has increased the difficulty of giving a strictly logical definition of an alkali; but the bodies that have usually been called by this name are, in some of their forms, familiarly known; they have also a sufficient number of properties in common, to distinguish them from other classes of bodies,† and this is the most important point to be attained in our arrangements. It is true also that their properties graduate into those of some of the earths; but it is sufficient to designate the latter as alkaline earths, and to leave the remainder of them to be called earths proper.

---

* For the details of these and of numerous other experiments, see Dr. Hare's original pamphlet, and his and my own various memoirs in the Phil. Trans. of Philadelphia; in Tilloch's Phil. Mag.; in the Annales de Chimie et de Physique; in Dr. Bruce's Journal, and in the American Journal.

Dr. Hare remarks, (Comp. p. 77,) that excepting the republication of his memoir in Tilloch's Phil. Mag. and in the Ann. de Chim. et de Phys. and a quotation of his results in Murray's System of Chemistry, they had been generally neglected. "Hence, (adds Dr. Hare,) a modification of the hydro-oxygen blowpipe was contrived by Mr. Brooke. Dr. Clarke, by means of this modification, repeated my experiments and those of Prof. Silliman, without any other notice of our pretensions than such as was calculated to convey erroneous impressions."

I regret to say that this omission, although made known, was never corrected, and that the experiments of Dr. Clarke, most of which had been, years before, performed and accounts of them published by Dr. Hare or myself, were entitled to no credit for originality; while the almost identity (in many cases) of the language in which they were described, with that used by us so long before, proves that the results with the two instruments were the same.

It is not pleasant to transgress the kind maxim, *nil de mortuis nisi bonum;* but truth obliges me in this instance to do it.

The claims of Dr. Clarke respecting the compound blowpipe were entirely unfounded.

Explanatory Statement.

The alkalies, when they are to be prepared pure for chemical purposes, are generally extracted from their saline combinations, and it is therefore necessary to premise, that a salt is composed of an acid and a base: the alkaline salts have, of course, an alkaline base, and the object of our processes is to separate the acid, and leave the base isolated, and free also from accidental bodies, commonly called impurities.

In giving the history of potassa, soda and ammonia, only two acids need be mentioned: potassa and soda, as they occur in commerce, are usually found combined with the carbonic acid; and ammonia both with that and with the muriatic acid. The carbonic acid, composed of carbon and oxygen, is a gaseous body, which when combined with the alkalies, blunts their properties, but it is easily removed from these combinations, partially by heat and completely by the superior affinity of lime. It is also entirely expelled by stronger acids, but a new salt is, in that case, formed; and in general the forming of such a compound, would rather retard than advance our progress towards obtaining the pure alkali. The muriatic acid is also a gaseous body: it cannot be expelled from the alkalies by heat: it can be displaced by the sulphuric acid, but that will only engage the alkali in a new combination: to remove it entirely, we employ lime in this case also, which will attract it away and leave the alkali free and pure.*

---

* Ammonia excepted, which no one arranges under the metals.

† It is scarcely necessary to add, that I do not include the new alkaline vegetable proximate principles, morphia, delphia, quinia, strychnia, &c.

AMMONIA—POTASSA—SODA—LITHIA.

GENERAL CHARACTER OF ALKALIES.

(*a.*) Caustic to the animal organs.

(*b.*) Volatilizable by heat, but, except ammonia, not decomposable by heat alone.

(*c.*) Combine with acids and form salts;† acids and alkalies are antagonists.

(*d.*) Very soluble in water, even in the state of carbonate; soluble also in alcohol.

(*e.*) Turn‡ most blue, purple, and other dark vegetable colors, to green; as tincture or infusion of violets, and of purple cabbage.

(*f.*) Turn most yellow vegetable colors to brown; as turmeric and rhubarb; and red to purple, as tincture of brazil wood.§

(*g.*) The colors altered by an alkali, are generally restored by a due proportion of an acid.

(*h.*) Unite with oils and form soaps; corrode woollen cloth; and are generally powerful solvents of animal matter.

(*i.*) Taste, acrid and peculiar; particularly different from that produced by acids; it is called the alkaline taste, and in a milder form, is observed in pearl ashes and soda.

SEC. I.—AMMONIA.||

Remark.—This alkali is placed first because of its relation to nitrogen, and hydrogen, which have been described.

---

* Had we begun with acids, an explanatory statement would have been necessary respecting alkalies and salts, as two of the most important of the acids, the nitric and muriatic, are extracted from saline combinations.

† The definition of alkali proposed by Dr. Ure, founded on the power of "combining with acids, so as to neutralize or impair their activity," would confound them with the earths and metallic oxides.

‡ The power to affect vegetable colors, continues even after combination with carbonic acid, which distinguishes the alkaline from the earthy carbonates. Ammonia being a volatile alkali, sometimes escapes by evaporation, and the original color is thus restored.

§ Bibulous paper, wet with these colored solutions, forms test papers, by which the application of colors is easily made. Litmus is not changed by alkalies, but if previously reddened, it is turned back by an alkali to its original color, and thus becomes a test.

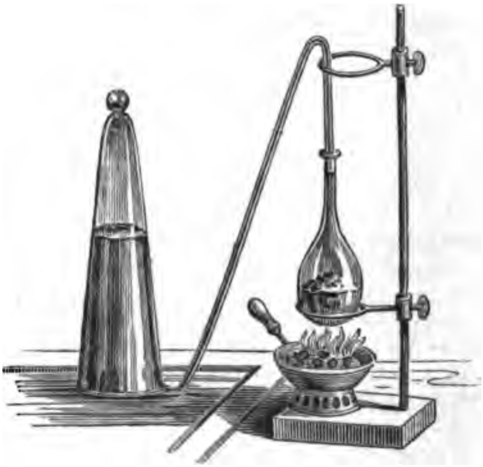
|| Called also the volatile alkali. Popular name *hartshorn*, because it was anciently distilled from the horns of the hart or deer, which, in common with other animal matter contain its elements.

1. **The name** is derived from that of sal ammoniac, or the muriate of ammonia, and this from the sandy country of Lybia,* (αμμοσ,) where the salt was first procured.

2. **Discovery.**—The gas was discovered by Dr. Priestley, by heating the aqueous solution of the shops; he collected the gas in vials filled with mercury, which was expelled by the gas.

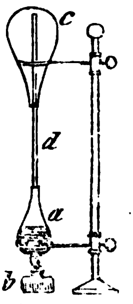
Process for obtaining gaseous Ammonia.

3. **Preparation.**



(*a.*) *From equal parts of powdered muriate of ammonia, and dry-slacked*† *quick lime*, intimately mingled, and heated moderately in a glass retort;‡ we receive the gas over mercury, as in the annexed cut of Dr. Hare.

It is very convenient to displace the common air, by conveying the gas, by a glass tube into an inverted glass vessel; as in the annexed figure, where *a* is the flask containing the materials; *b* a spirit lamp, for heat; *c* the recipient, and *d* the connecting tube. It is obvious that this process is founded on the levity of the gas, which displaces the air of the vessel.



(*b.*) *Heat the aqueous solution of ammonia* to expel the gas; but this is not an eligible mode, as the water distils over, is condensed above the mercury, and reabsorbs the gas. In the process 3, (*b.*) we know when the recipient is full, both by the pungent smell, and by bringing a feather dipped in muriatic acid near the mouth of the vessel, when, if the gas is overflowing, there will be a white cloud of regenerated muriate of ammonia. When it is important to have the gas very dry, unslacked lime should be used; but it is apt to adhere to the glass and break it.

4. **Physical properties.**

---

* Called Ammonia. Some say in allusion to the sand; others to the temple of Jupiter Ammon.

† That is, slacked with such a portion of water, as to remain dry.

‡ In all operations for collecting gases over mercury, ground, tubulated glass retorts are better than flasks, as, from the pressure, the latter are apt to leak at the cork.

(*a.*) ***Transparent and colorless; smell, highly odorant and pungent.***—Agreeable, if largely diluted with air; it causes a sharp prickling sensation in the hands, and if the skin is moist, it is absorbed, and is almost corrŏsive; combining with the moisture on the eye-balls, it causes a sensation of intolerable pain. It is therefore decidedly caustic, and could it be made solid without combination, it would doubtless act on animal matter with as much energy as the fixed alkalies do.

(*b.*) *Specific Gravity* 0.5957, air being 1.—*Weight*, 18.17, at the medium temperature and pressure.

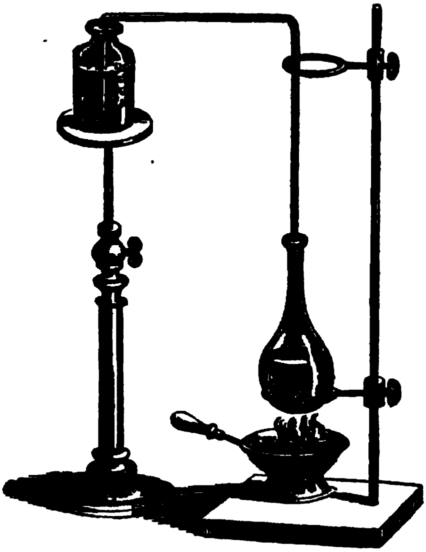
(*c.*) *Hostile to animal life.*—An animal immersed in it instantly dies. It kills by suffocation and excoriation; admitted into the fauces it is intensely painful; it causes a violent spasm as soon as it reaches the glottis, and produces the most distressing coughing, and a lasting irritation.

5. CHEMICAL PROPERTIES.

(*a.*) *Instantly absorbed by water*, a drop of which being admitted and agitated with the gas, the mouth of the vessel being closed by the finger, and then opened under the fluid, it rushes in as it would into a vacuum. Ice melts in the gas more rapidly than it would in the fire; if passed up into a jar of gas standing over mercury, the metal rises rapidly as the ice melts, and the gas is absorbed to form liquid ammonia.

(*b.*) *Ice-cold water absorbs* 780 *times its volume of this gas.*—(*Thomson.*) Sir H. Davy has stated its absorbability at 475; water easily absorbs this quantity, and then holds about one third of its weight of the gas. Sir H. Davy's more recent statement was, that 670 times its volume of this gas, was condensed into one of water.

(*c.*) *Aqua Ammoniæ* is prepared in pharmacy and in chemistry, by passing ammoniacal gas, from equal parts of slacked lime, and muriate of ammonia, heated in an iron bottle, through ice cold water, contained in Woulfe's bottles, the contents of the first being rejected as impure. For a figure of Woulfe's apparatus, see muriatic acid. I annex a cut from Dr. Hare, of an apparatus which will answer for a common experiment. It needs no explanation.



(*d.*) *The aqua ammoniæ smells like the gas;* it is a very useful reagent, and an efficacious medicine.

The more highly water is impregnated with ammonia, the lighter it is,[*] as appears from the following table of Sir H. Davy, in which the proportions are by weight.

Sp. gr.	Ammonia.	Water.
0.8750	32.50	67.50
0.8875	29.25	70.75
0.9000	26.00	74.00
0.9054	25.37	74.63
0.9166	22.67	77.93
0.9255	19.54	80.46
0.9326	17.52	82.48
0.9385	15.88	84.12
0.9435	14.53	85.47
0.9476	13.46	86.54
9.9513	12.40	87.60
0.9545	11.56	88.44
0.9573	10.82	89.18
0.9597	10.17	89.83
0.9619	9.60	90.40
0.9692	9.50	90.50

Dr. Ure[†] has given another table; he thinks the numbers in Sir H. Davy's too high by about 1 per cent. A vial containing 224 grains of distilled water, will contain only 216 grains of strong aqua ammoniæ.

(*e.*) *Alcohol can be impregnated in the same manner*, and it may be done at the same time, in a separate bottle of the apparatus.

(*f.*) *Ammoniacal gas extinguishes flame, but burns slightly;* very evidently, if taken in quantities not less than a pint, and having at the same time access to the air, when it burns as it rises, with a a voluminous yellow flame.[‡] If it were collected in large jars, in the manner already described, 3. (*a.*), it would doubtless burn with a flame still more conspicuous.

(*g.*) *If introduced into oxygen gas, in the form of a jet, it burns*, and the products are water and nitrogen gas; the hydrogen uniting with the oxygen, and leaving the nitrogen behind.

6. ANALYSIS, COMPOSITION, AND PROPORTION OF ELEMENTS.

(*a.*) *By the electric spark*, passed through the gas, standing in a detonating tube, over mercury. It requires two or three hundred discharges to effect the decomposition.

---

[*] The same fact is observed in the solutions of its salts.

[†] Dict. 2d Ed. p. 142.

[‡] Am. Jour. Vol. VI, p. 185.

(*b.*) ***By furnace heat***, the gas being driven through a porcelain tube; but the decomposition, is in this way very tardy, and requires an intense heat to produce a few bubbles of gas.* It is much better done in an iron tube, filled with coils of iron wire, or copper, silver, gold, or platinum; their relative energy corresponds with the order in which they are named above, but iron is by far the most powerful. The explanation of this decomposition, appears, at first, not very easy; since the metals do not combine with either of the constituents of ammonia, and are not altered. Probably they act by transmitting heat; the metals neither gain nor lose in weight, and appear to act as conductors only. The result of the experiment gives 3 volumes of hydrogen and 1 of nitrogen gas, in mixture; electrization gives the same result; by weight, 17.64 hydrogen, 82.35 nitrogen; as the gases are condensed into half their volume, the specific gravity of ammonia is not that of nitrogen, .9782+3 hydrogen .2083=1.1865, but half of this =.593.†

A soft, pasty, semi crystallized mass is obtained, when a globule of mercury is galvanized, or a piece of potassium laid, in a cavity, in a solid ammoniacal salt, particularly in muriate of ammonia; it resembles an amalgam, and hence it has been supposed that either hydrogen or nitrogen, or both, has a metallic base; but the substance has never been obtained isolated, and no satisfactory conclusion can be built upon it.

(*c.*) *By oxygen.*—100 measures of ammonia +50 of oxygen, being detonated over mercury in a tube, the oxygen disappears; then add 30 or 35 measures more of oxygen; detonate again; one third of the entire diminution is oxygen, and double this is the hydrogen; the nitrogen remains, deducting any that may have been introduced with the oxygen gas; this result corresponds with that under (*b.*) giving 3 volumes of hydrogen, and 1 of nitrogen, which, as they exist in a state of combination in ammonia, are condensed into 2 volumes; the decomposition of ammonia, therefore, doubles its volume; it is, however, no longer ammonia, but a mixture of its constituent gases, hydrogen and nitrogen.

(*d.*) The mixed hydrogen and nitrogen gases, obtained by igneous or electrical decomposition, may be analyzed in the same manner, by detonation with oxygen, and will give the same result.‡

---

* As the ammonia is instantly absorbed by water, none of it will pass through that fluid, and the mixed gases obtained, are of course hydrogen and nitrogen. I have repeatedly carried this experiment, by the aid of bellows, almost to the fusion of the porcelain tube, without obtaining a cubic inch of gas; while if there be iron in the tube, the gases come over, abundantly.

† .595 is the number which we have quoted, p. 232; Dr. Thomson states it at .590.

‡ The analysis by chlorine is very elegant and easy. See that topic. The chlorine removes the hydrogen, and leaves the nitrogen.

7. SYNTHESIS.

(*a.*) *Hydrogen gas and nitrogen gas, mingled in the proper proportions, do not form ammonia, nor would they ever do it*—their specific caloric opposes the union; they would remain always a mere mixture.

(*b.*) *Hydrogen in its nascent state, meeting with nitrogen, forms ammonia;* this happens when hydrogen is disengaged from moistened iron filings, included in a jar of nitrogen.

(*c.*) *Nitric acid, acting on tin or on phosphorus, forms ammonia;* water furnishing the hydrogen and the acid the nitrogen; it is then disengaged by a little lime which arrests the acid, and the ammonia is perceived by its odor, and by a white fume with muriatic acid.*

(*d.*) *Ammonia is formed during animal decomposition;* both its elements being evolved from the animal matter, and uniting at the instant; this is the origin of ammonia in stables, privies, and other similar places.

8. ACTION ON COLORS.†

(*a.*) Red tincture of alkanet becomes blue;‡ blue infusion of cabbage, green; diluted yellow tincture of rhubarb or turmeric, brown,

---

* Ann. de Chim. et de Physique, XXIV. 295.

† I am not aware that any reason has been suggested for these changes of color; certainly none has occurred to me that is satisfactory. As a general fact, permanent changes of color depend on changes of composition, as is evinced in innumerable cases; for instance, red lead and red precipitate contain oxygen, a colorless body, and metals, one of which is white and the other gray; indigo is intensely blue, but becomes green by losing oxygen. In the case of the test colors, the color is permanent, as long as the coloring matter is not decomposed, which happens eventually, and perhaps we may say that a peculiar combination takes place between the coloring matter and the acid or alkali, although we can give no reason, any more than in other cases, why these particular colors should result, or why there should be any change of color.

The autumnal hues of the leaves of trees probably depend on similar causes; that is to say, on the fuller developement of acid or alkali, by the variations of temperature; for these agents always exist abundantly in vegetable bodies, and particularly in their fluids. It is not impossible that galvanic principles, may aid in producing and modifying the effects.

If any person would examine the leaves of the sugar maple, for instance, just before the first autumnal frosts, and while they are still green, he could easily decide whether acid or alkali were predominant, or whether either was to be found in a state of freedom; then let him examine the leaves after they have turned red, a color which we should of course attribute to the developement of acid. A similar examination should be made of the chemical condition of leaves exhibiting other colors produced by decay, as the yellow of the hickory, the brown of several species of oak, &c. and so of the different colors observed in leaves of the same trees in the various stages of decomposition.

In the American Journal, Vol. xvi, p. 215, there is a reference to an essay on this subject, in the Ann. de Chim. et de Phys. Aout, 1828, in which it is stated, that the colored parts of vegetables, appear to contain a particular substance, called by Prof. De Candolle, *chromule*, and the autumnal change in the color of leaves is attributed to the fixation of oxygen, and to a sort of acidification of the *chromule*.

‡ We owe this very convenient test, to Dr. Hare.

&c.; acids bring the colors back, as has been stated in giving the general characters.

(*b*.) In applying these colors, we may fill a small tube stopped at one end, or an essence vial, with the colored fluid, and with a finger on the mouth, turn it upward into a jar of the gas standing over mercury; instantly the color will change, and the gas be absorbed.

9. CONDENSATION OF THE GAS, BY COLD AND PRESSURE.

This was accomplished by Mr. Faraday,* by disengaging it in sealed syphon tubes, from chloride† of silver which absorbs it in large quantities, 100 grains absorbing 130 cubic inches of the gas. The leg of the syphon containing the chloride, was heated to 100° Fahr. and the other leg kept cold by ice. Ammoniacal gas was evolved, and part of it was by the pressure of the rest, reduced to the liquid state. It was a colorless fluid; its refractive power was greater than that of water, and at 50°, its pressure equalled 6.5 atmospheres; its specific gravity was 0.76, water being 1.

10. PROCESS IN THE ARTS.

By the distillation of bones, and other firm parts of animal substances, ammonia is generated, by the reaction of its elements, but it is more or less combined with carbonic acid. Among the elements of animal matter, we always find hydrogen and nitrogen. The ammonia obtained is impure, mixed with animal oil, &c. and is purified by combining it with the muriatic or sulphuric acid, and then decomposing this ammoniacal salt by quick lime, in the manner already described. In the manufactories, bones and horns are commonly employed, and sometimes the refuse of the slaughter houses. An iron retort or still is generally used; the bones are introduced roughly broken, and a strong heat applied. A tar like substance, oil, and very fetid gases, are evolved, which should always be burned as they are both noxious and disgusting. Valves are sometimes fixed in the apparatus to prevent the return of common air; this would of course happen when the apparatus grows cold, and the air by mingling with the inflammable gases, might occasion an explosion, when the fire is lighted again. Animal charcoal, mixed with phosphate of lime, remains in the iron vessel.‡

11. PHARMACEUTICAL PROCESS.

To procure aqua ammoniæ, we may employ either a still§ or Woulfe's bottles; the latter are always used in philosophical laboratories; the proportions of the materials are 1 to 2 parts of slacked lime, and 1 of pulverized sal ammoniac, and the gas is received in water, equal in weight to the salt employed; it is kept cold by ice or snow, or at least by cold water often renewed. When the gas ceases, the addition of a little water to the materials in the retort, will renew the flow of gas, and produce complete decomposition; ten pounds of sal ammoniac should produce thirty pounds of aqua ammoniæ, sp. gr. .950, and containing about 12 per cent. of ammonia.* The Edinburgh college prepare it of the strength, .989; that of London, .960. —*Ure.*

---

* Phil. Trans. 1823, p. 196. † Muriate. ‡ Gray's Op. Chem.

§ In the large way, one of iron is used with a stone-ware head, and stone-ware bottles may be used for the condensation.

12. NATURAL SOURCES.

From the decomposition of animal substances, as in privies and stables,† &c.; it is probable that ammonia is produced generally during the spontaneous decomposition of animal bodies; a pungent, reviving, and antiseptic gas thus springs up, from the very bosom of putrefaction.

The Chenopodium vulvaria emits this gas in the act of vegetation, and many flowers, even those with an agreeable odor‡ do the same.

13. GENERAL INFERENCE.

In destructive distillation, and in spontaneous decomposition, the appearance of ammonia indicates nitrogen, and of course hydrogen.

This remark will apply not only to animal substances, but to plants, when they afford ammonia, as all those do which putrefy with an animal odor.

14. POLARITY.

Ammonia is attracted to the negative pole in the galvanic circuit, and is therefore electro-positive.

15. COMBINING WEIGHT 17—made up of 1 proportion of nitrogen 14, and 3 of hydrogen = 17.

16. MEDICAL AND OTHER USES.—These are important; taken internally, in the proportion of 8 or 10 drops to a wine glass full of water, ammonia is a powerful and valuable stimulant, producing the most useful effect of alcohol, but without its mischiefs. It is also an antacid.

Externally, it is a rubefacient, but it is generally used in the form of volatile liniment, made by agitating aqua ammoniæ in a vial with olive oil. Ammonia is a very valuable antidote to poison. Either the aqua ammoniæ, the carbonate, or the volatile liniment may be used externally, and the two former internally.§

---

* The iron bottles in which quicksilver is brought, answer very well for the decomposition of sal ammoniac, and the muriate of lime is easily extracted from them by hot water.

† In these places, the ammonia is mixed with fetid gases; the pungency belongs to the former, and the disagreeable odor to the latter. The ammonia is often so abundant as to produce a white cloud, when, in these places, the stopper is withdrawn from a vial of muriatic acid. In Europe, ancient hotels are sometimes filled with ammoniacal exhalations, arising from the privies within the premises.

‡ Jour. de Phar. Feb. 1824, p. 100; also, Am. Jour. Vol. X, p. 190.

§ See Am. Jour. Vol. XVI, p. 183.

It is given to animals, to relieve the inflation occasioned by eating excessively of green grass, clover, lucerne, &c. It is of the most important and extensive use in practical chemistry.

Remarks.

Ammonia is one of those gases which destroy animal life, when it is mingled, in only a small proportion, with the air that is respired.

It was found by Chevallier in iron rust, in situations exposed to animal effluvia; it was formed when clean iron that had been ignited was boiled in pure water, and it appears to be always formed when iron decomposes water in contact with air; the water affording the hydrogen, and the air the nitrogen.

It appears also to exist in natural iron ores, such as the red hematite of Spain, the micaceous ore, and the Jenite of Elba.*

It has already been mentioned that ammonia is formed when moistened iron filings are placed in nitrogen over mercury, as ascertained by Dr. Austin, in 1788.

SEC. II.—POTASSA.

1. NAME.

From the potashes of commerce; and their name is obviously derived from ashes, and the pots (called potash kettles,) in which the lixivium is boiled down. Some of the old names were, vegetable alkali—salt of tartar—salt of wormwood, and alkali of nitre, in allusion to the principal sources from which the alkali is obtained.

2. PROCESS OF THE ARTS.†

The watery lixivium‡ of the ashes§ mixed with quick lime, being boiled down in the iron pots or kettles, the residuum is ignited, and then constitutes the potashes of commerce. Placed in a reverberatory furnace, and stirred while the flame plays upon it, it becomes white, and is then the pearlashes of commerce; it is thus purified by fire only, by the destruction of extractive and other combustible matter, and the dissipation of volatile principles, gases, &c.; it loses generally about 10 or 15 per cent. of its weight.||

The purest alkali is obtained from the mutual action, in a red hot iron pot, of nitre 1, and tartar 2; the basis of both salts being potash,

---

* Am. Jour. Vol. XIII, p. 181.

† To render this process intelligible, nothing more need be premised than that besides impurities, the potash of commerce is found combined with carbonic acid, which the lime detaches by its superior affinity, and thus liberates the alkali.

‡ This word is used to denote a lye made with ashes, and is derived from the Latin word *lix*, denoting this preparation, and *Lixa* is a worker in this branch of the Arts.—*Parkes.*

§ When wood is burned, the ashes constitute about 1-200th part of its weight.—*Ure's Dict.*

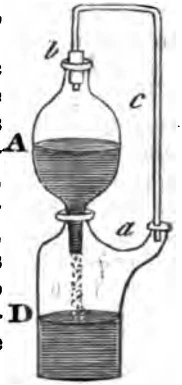
|| See Dr. Roger's account in Am. Jour. Vol. VIII, p. 304.

and the acids being destroyed by their action on each other; also by igniting nitre in a crucible of gold.

3. PREPARATION OF POTASSA, OR PURE POTASH.

Take 1 part potashes, or pearl ashes, and good quick lime 2, with abundance of water; boil for an hour, in an iron or copper kettle, till the fluid neither effervesces with acids, nor precipitates lime water.[*] Strain it through a coarse brown towel, stretched on a frame with tenter hooks, and hot water should be repeatedly passed through, until we have used ten times as much as the weight of the carbonate of potash employed. The caustic fluid may be put up in black bottles, and allowed to settle over night; the next morning it may be drawn off by a glass syphon. To avoid burning the mouth, the syphon tube may be filled with water, and the finger being pressed upon the mouth of the longer leg, the shorter may be dexterously turned into the bottle's mouth, without breaking the column in the syphon, the water in which may be allowed to run off, and the fluid is then saved for evaporation.

In general, filtering succeeds badly with caustic alkalies, unless very weak, as they are apt to corrode the filters, and paper can scarcely be used, unless for small assays. If the filtering is slow, the carbonic acid of the air is apt to combine with the alkali, and to prevent this, Mr. Donovan contrived the annexed apparatus, in which A is the filtering funnel, whose mouth is obstructed by folds of linen;[†] D is the receiving vessel, and *c* is a connecting tube, to prevent, at once, any communication with the external air, and any accumulation of pressure in the lower vessel.[‡]



(*b*.) Boil the solution[§] down to dryness in a clean iron kettle; fuse the mass in a silver crucible; pour it out on a marble slab; break it up, without delay, and cork it tight from the air in a glass bottle. Cream of tartar, ignited in a crucible, dissolved in water, filtered, boiled with sufficient lime, obtained clear by subsidence and decantation, and solid by evaporation in a silver vessel, to the consistence of oil, gives a cake of the pure hydrate of potassa, without the trouble of using alcohol. It must be put up immediately, in close bottles.—*Ure.*

---

[*] Taking care, provided the solution of alkali is strong, to dilute it with pure water; otherwise it may precipitate the lime, by seizing the water, and thus give a delusive indication.

[†] Better by fragments of glass, coarser below and finer and finer above; water is passed through, both before and after an experiment, to remove impurities, and thus a permanent filter is obtained for acids and other corrosive fluids. D. O.

[‡] Ann. Phil. 26, 115, and Turner, 2d Ed. p. 405.

[§] For a table shewing the real quantities of alkali in aqueous solutions, see Henry, Vol. 1, p. 528, 10th London Ed.

This substance, mixed with lime, and fused and cast in cylindrical moulds, forms the caustic called *lapis infernalis*, or lapis causticus of the shops. It is said that oxygen gas is disengaged, during its solution in water, and that it varies apparently with the impurity of the specimen.

(*c.*) *It is now caustic, but contains all the soluble impurities*, chiefly salts, carbonate, muriate, and sulphate of potassa, silex, and oxide of iron and manganese, &c.; to purify it, dissolve it in good alcohol; the solution will be wine red; the watery solution of the salts below is immiscible with the alcoholic solution of the alkali, and the solid impurities are at the bottom. Evaporate the alcohol,* and finish the process in a silver basin or crucible, with moderate ignition; then break up the mass, and secure it from the air.

It still contains a little carbonic acid, arising from the reaction of the alkali on the alcohol, or absorbed from the air. The addition of barytic water, previous to the last evaporation, will entirely remove the carbonic acid.

(*d.*) *Hydrate of Potassa.*—This is the substance above described. If the whole of the alcohol be not expelled, the alkali will, on cooling, crystallize in single or double plates, needles, or tetrahedral pyramids. This hydrate contains one proportion of water, 9, and one of potassa, which, as we shall see under potassium, is represented by 48, and its equivalent is therefore 57. Heat alone will not separate the water from it; if it is urged, the alkali will rise along with the water, which can be separated only when it enters into new combinations.

4. Properties.

(*a.*) Solid at common temperatures; melts at 300°, and is volatalized at low ignition, with a visible cloud of caustic fumes, highly acrid; color, white or gray; taste, when strong, burning and intolerable; corrodes and destroys animal and vegetable substances, subverting completely the organic texture, and in a word, it possesses, in perfection, and in full energy, all the characters of alkalies, mentioned in the introduction to their properties.

(*b.*) It affects vegetable colors as ammonia does; in addition to the colors enumerated under ammonia, it may be mentioned that a strong infusion of the dried flowers of the red rose, answers very well.—*Parkes.*

(*c.*) *Deliquesces rapidly in the air*, and by absorbing carbonic acid, becomes partially mild again. It acquires moisture so rapidly, from the air, as speedily to change the color of any of the alkaline test papers upon which it is laid. Turmeric paper shews it well. Crystallized hydrate of potassa, produces cold during its solution in water, while the solid alkali evolves heat.

---

* Or distil off and save the first half of it, in a receiver, as it will be alcohol of a good quality; the remainder will contain more water, and is scarcely worth saving; there is danger, besides, if we evaporate too low in a glass vessel, that it will be attacked by the alkali.

5. Composition.—See potassium.

6. Polarity.—*Electro positive ;* it is attracted to the negative pole in the galvanic circuit.

7. Origin.

From vegetables that have no connexion with salt water. Plants yield more than trees; the branches more than the trunk; the small branches more than the large, and the leaves most of all. Herbaceous plants yield more ashes and more alkali than wood. Fumitory[*] is said to yield more salt than any other plant, and wormwood more alkali than any other vegetable.

One thousand pounds of the following vegetables yielded saline matter in the following proportions.

Wormwood, - -	748	Fumitory, - -	360
Stalks of sunflower,	349	Beech, - - -	219
Stalks of Turkey Wheat, or		Elm, - - -	166
Maize, - - -	198	Fir, - - - -	132
Vine branches, - -	162 6	Oak, - - -	111
Fern, cut in Aug. - -	116	Heath, - - -	115
Sallow, - - -	102	Aspen, - - -	61
Box, - - -	78		*Kirwan.*

Fern leaves are used in Yorkshire, in England, in cleaning cloth for fulling, and appear to afford alkali already developed.

In the Highlands of Scotland, soap is made from the alkali obtained from the ashes of peat.

The resinous and odorous woods afford little alkali; hence the ashes of pine wood are regarded in families, as worthless for soapmaking.

Potatoe tops yield a great deal of alkali.

The alkali of ashes arises principally from salts existing in the vegetable juices, and modified by the fire.[†]

8. History.

In an impure state, it was known to the ancients; Pliny states that the Gauls and Germans formed soap of ashes and tallow; and Dr. Thomson thinks that their ashes were the same with our potash.

---

[*] In Mr. Kirwan's table, quoted in the text, Fumitory is stated to yield but about half as much saline matter as wormwood.

[†] As the alkali of vegetables is not an essential constituent, and is derived from the soil, the quantity which any plant will afford, will depend on the qualities of the earth, in which it is raised. Hence we can account for the discrepancies of different experimenters respecting the relative quantities of alkali afforded by different plants. —J. T.

Indeed it was not known in purity until 1786, when Berthollet gave the process by alcohol.

In the ruins of Pompeii, which was overwhelmed by an eruption of Vesuvius, A. D. 79, " a complete soap boiler's shop was discovered, with soap in it, which had evidently been made by the combination of oil and alkali," and it was perfect, although it had been made more than seventeen centuries.*

9. TESTS FOR POTASH.†

1. With an excess of tartaric acid, it forms a precipitate, which, when stirred with a glass rod, forms peculiar white streaks.

2. Muriate of platinum gives a yellow precipitate, a triple salt of platinum and potash, forming, by gentle evaporation to dryness, and the addition of cold water, " small shining crystals."

3. Potash is precipitated by nothing.—*Turner.*

10. PHARMACEUTICAL PREPARATION AND MEDICAL USE.

The pharmaceutical preparation does not differ materially from that which has been already described for the purification of the alkali.

The principal use of caustic potash is as an escharotic; the cylindrical masses found in the shops, are often impure, and partially carbonated and deliquesced, and will sometimes disappoint the practitioner. That which is carefully prepared by the process 3. (*a.*) and (*b.*) is much more powerful. Potash is mixed with lime to render it milder, and less deliquescent; this is the *kali causticum cum calce*, of the pharmacopeias. The pure alcoholic potassa, prepared by the process 3. (c.) is a very certain caustic, and if fused at ignition, in the conclusion of the process, broken up immediately, and put up in close vials, it discovers, even in several years, no disposition to deliquescence, and preserves its crystalline structure.‡

Caustic alkali has been used as a lithontriptic. When the concretions consist of uric acid, or urate of ammonia, there is often a favorable effect produced, but it is difficult to persist long in the use of such a remedy, either by the mouth or by injection into the bladder.

When there is to be a long perseverance in the use of alkaline remedies, they must be taken in a milder form, as will be mentioned under their carbonates.

---

* Parkes' Chem. Essays.

† The nitrate, oxalate, or oxide of nickel, fused with borax, will give a blue color with nitre, feldspar, or any substance containing potash, and the presence of soda does not prevent the appearance of the color; if nickel contains cobalt, the glass will have a brown color.—*Am. Journal, Vol. XVI, p.* 387.

‡ The late celebrated Dr. Nathan Smith used to obtain this alkali from the laboratory, in all cases when he wished an energetic and certain effect, and it never disappointed him. I have many times gone through the whole labor of preparing it and although the processes are troublesome, the result is very valuable, both to chemistry and medicine.

Remarks.—Common ashes effervesce powerfully with acids, and they easily give a solution with hot water, which affects the taste with the perception of alkalinity, and the test colors with their appropriate changes.

The most familiar use of a lye in families, is in soap making, and a principal cause of failure is, that the alkali is not rendered caustic by the application of a sufficient quantity of good quick lime. The density of the solution is ascertained by the family hydrometer, an egg, which floats when the solution is sufficiently dense; but it may be dense without being caustic, and if it is not caustic, it will act but partially in forming soap. It should not effervesce with acids; if it does, it is proof that the carbonic acid has not been all withdrawn, and it may be necessary to pass it through more lime. If it is too weak from having too much water in it, this is easily removed by boiling it down. The subject of saponification will be mentioned again under oils, vegetable and animal. Lye has a valuable antiseptic effect, and is often used in families, as a part of poultices, and also to counteract the tendency of wounds towards tetanus.

This alkali, as it separates almost every base from acids, and as it acts with great energy upon many substances, is of great utility in chemistry. It is an immediate antagonist of acids, and forms salts with them.

Alkalimeter.

This simple instrument is founded upon the fact that 100 grains of pure subcarbonate of potash, are saturated by 70 of strong sulphuric acid. The acid is placed in a glass tube graduated into 100 equal parts, and the tube to the extent of the graduations, is then filled with water. The purity of the alkali to be tried, will be ascertained by the proportion of this diluted acid which it requires for perfect saturation; if there be 60 per cent. then 100 grs. will require 60 divisions, and so in proportion; if pure, it will require it all.

If we would ascertain the proportion of pure potassa in the salt, then we must employ 102 grains of the acid, and dilute it with the same quantity of water, requisite to fill the tube.—*Ure.*

This alkali is of vast importance in glass making, soap making, in medicine, in domestic economy, and in various arts, and it constitutes an important article of commerce, especially from the United States to Europe.

POTASSIUM.

1. Discovery—by Sir H. Davy, in October, 1807.*

---

* See the Bakerian lecture for that year, in the Philos. Trans. Although soda has not been, as yet, described in this work, I will give the account of the discovery of its decomposition in connexion with that of potassa, as the facts in the two cases are very similar, and are in both perfectly intelligible. A more particular statement of the properties of sodium will be afterwards given.

2. Process.

DECOMPOSITION OF POTASH AND SODA.

1. *By galvanism.*—The first attempts of Sir H. Davy were made upon aqueous solutions of potash and soda, but the water alone was decomposed. He then kept the potash in perfect fusion by an ingenious contrivance; it was contained in a spoon of platinum, which was, in the first instance, connected with the positive side of a battery of one hundred pairs of six inches, highly charged, and the connexion from the negative side was made by means of a wire of platinum. A most intense light was exhibited, at the negative wire, and a column of flame arose from the point of contact. When the spoon was made negative, and the wire positive, a vivid and constant light appeared at its point, and aëriform globules which inflamed in the atmosphere rose through the potash.

A small piece of pure potash, slightly moistened by the air, so as to give it conducting power, was placed on an insulated disc of platinum, connected with the negative side of the battery of the power of 250 pairs of 6 and 4 inches, in a state of intense activity and a platinum wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open atmosphere.

There was a fusion of the potash at both surfaces—a violent effervescence at the upper, and at the lower, 'small globules, having a high metallic lustre, and being precisely similar, in visible characters, to quicksilver, appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained and were merely tarnished and finally covered by a white film which formed on their surfaces.

These globules were the basis of the potash; they did not proceed from the platinum, for they appeared equally, whether copper, silver, gold, plumbago, or even charcoal, was employed for completing the circuit. The air had no agency in producing the globules, for, they were evolved when the alkali was placed in a vacuum.*

The substance was likewise produced from potash, fused by means of a lamp, in glass tubes, confined over mercury, and furnished with hermetically inserted platinum wires, by which the electrical action was transmitted. But the glass was so rapidly decomposed by the substance that the operation could not be carried far.

The substance produced from potash remained fluid at the temperature of the atmosphere, at the time of its production.

---

* I repeated these experiments in 1810, and then obtained the metalloids; see Bruce's Journal. Dr. (now Pres.) Cooper first decomposed potash in this country by the gun barrel and furnace.

THEORY OF THE PHENOMENA.

These decompositions agree perfectly with those which have been before described; oxygen is evolved at the positive wire, and the combustible with which it was united at the negative. When the solid potash or soda was decomposed in glass tubes, the new substances were always evolved at the negative wire, and the most delicate examination proved that the gas liberated at the positive wire was pure oxygen, and, unless more water was present than was necessary to give conducting power to the alkali, no gas whatever was given out at the negative wire.* The synthetical proofs were equally satisfactory.

The bases of both alkalies, when exposed to the atmosphere, became tarnished and covered with a white crust, which immediately deliquesced; water was decomposed, a farther oxidizement took place, more white matter was formed, and the whole became a saturated solution of fixed alkali. When the metallic globules were confined over mercury in oxygen gas or common air, an absorption took place, a crust of alkali instantly formed, and, for want of moisture the process stopped, the interior being defended from the action of the gas. "When the substances were strongly heated, confined in given portions of oxygen, a rapid combustion with a brilliant white flame was produced; and the metallic globules were found converted into a white and solid mass, which, in the case of the substance from potash was found to be potash, and in that from soda, soda."

2. BY THE FURNACE.

(*a.*) The next spring, 1808, potash was decomposed in a gun barrel, in Paris, by Gay Lussac and Thenard.

(*b.*) *Very many precautions are necessary to secure success.*†

(*c.*) *Principal particulars.*—Provide a clean sound gun barrel bent, so that the middle shall be curved a little downward, while the end in which the potash is to be placed, shall incline gently upward, and the other end downward; it must be protected by a very refractory lute, made of coarse siliceous sand and potter's clay, with as much sand as can possibly be worked in, and dried with extreme slowness; place the tube across a furnace; potash in fragments is put into the elevated end out of the furnace; this is the breech of the gun barrel, and the breech pin is now put in with a lute; clean iron turnings are introduced into the belly of the tube in the part which lies in the furnace; a stop cock and tube of glass bent downward at right angles, are fixed at the other end; the glass tube dipping into oil; both ends are kept cold by water or ice, till a great heat is raised by a powerful bellows blowing with a large orifice, so as to introduce abundance of air; the potash which should have been previously ignited, before its introduction into the tube, is then slowly melted by a portable furnace, and running down upon the ignited iron, is decomposed; its oxygen is fixed in the iron, and hydrogen gas being abundantly disengaged from the tube, holding potassium in solution, and being spontaneously inflammable, it flashes frequently and with intense brightness; the potassium rises in vapor and congeals in the cold end of the tube; it is then cut out by a knife dipped in naptha and is preserved under that substance. It may be melted beneath it, and is readily moulded by the fingers smeared with naptha, into any form and into pieces of convenient size.

---

* Some have supposed that the hydrogen combines with the pure alkali to form the metals.

† See Recherches Physico-Chimiques; also, my translation of the Memoir of Gay Lussac and Thenard, in the Boston Edition of Henry's Chemistry, 1814; also Annales de Chimie, LXV, 325; Memoires d' Arcueil, II, 299.

The great difficulty is in preserving the gun barrel from oxidation and fusion.[*]

Curaudau of Geneva, in the same year, shewed that potash might be decomposed by charcoal alone, by mixing it in powder with twice its weight of dry carbonate of potash, and heating the mixture strongly in an iron tube or spheroidal iron bottle. Prof. Brunner has improved this process. His apparatus is a spheroidal wrought iron bottle, of one pint in capacity, and half an inch thick; a bent gun barrel, ten or twelve inches long, screws into the mouth of the bottle; the apparatus is well luted, and the gun barrel protected by iron wire wound around it, dips into a vessel of naptha, kept cold by ice. In one experiment, 6 oz. of iron filings, 2 of charcoal, and 8 of fused carbonate of potash, were intimately mingled and heated in a furnace, when 140 grains of potassium were obtained. It appears, according to the original observation of Sir H. Davy, that "potash or pearlash is easily decomposed by the combined attractions of charcoal and iron; but, it is not decomposable by charcoal, or, when perfectly dry, by iron alone. Two combustible bodies seem to be required by their combined affinities for the effect; thus, in the experiment with the gun barrel, iron and hydrogen are concerned."

---

[*] For improved processes, see Ann. of Phil. New Series, VI, 283; Quarterly Journal of London, XV, 379; and Annales de Chim. XXVII, 340; also, Am. Jour. Vol. VIII, p. 372. It would be difficult, without an amount of detail which is inconsistent with the limits of this work, to state all the circumstances that influence the success of this difficult process. Soon after the discovery of this method of obtaining potassium, and for several years after, I labored much in this field, having gone many times, through every part of the operation, from the preparation of the caustic alkali to its decomposition, and the evolution of its metal; I was a coadjutor at different periods, in these experiments, with Dr. Hare, Prof. Dewey, and Prof. Olmsted. The statements of Gay Lussac and Thenard, are extremely precise and very full; perhaps I might have added some things from my own experience, but it is rendered unnecessary by the fact, that easier means have been discovered, and potassium, from being one of the dearest of all substances, is now within the reach of every one.

It would seem, however, that charcoal alone has succeeded in the hands of Wohler, who employed the cream of tartar, after being heated to redness in a covered crucible. The tartar may be calcined in the same iron bottle in which it is to be decomposed, and it is advantageous to mix a little charcoal with the tartar previous to calcination; 300 grains have been obtained from 24 oz. of crude tartar. Prof. Berzelius is said to have obtained half a pound at one operation.*

4. PROPERTIES.

(*a.*) At 60° or 70° Fahr. it is imperfectly fluid; perfectly so at 100°, and of course at a higher temperature; when melted under naptha, it cannot be distinguished from mercury; at 150°, two globules will run into one; at 50°, it is a soft solid, plastic in the hand; at 32° or lower, it is brittle; breaks with brilliant lustre; and when broken, exhibits through a microscope, a crystallization in facets very white and splendid; at about the heat of ignition, it is volatile, rises in vapor and if air and moisture are excluded, condenses unaltered.

(*b.*) It is a perfect conductor of heat and electricity.

(*c.*) Sp. gr. about 0.865, (G. L. and Th.) 0.876, Bucholz or from .8 to .9, water being 1. Davy. That obtained by chemical means, is a little heavier, owing to carbon or iron combined with it, but it is sufficiently pure for experiments.

(*d.*) In the air or by moisture, it is oxidized and becomes again caustic potash; it cannot be preserved except under naptha; if that fluid has been recently distilled, and the vial is full of the fluid, the potassium may be kept under it for years, only it will collect a film of soap around it; the metal may be examined in the air, if covered with a film of naptha.

5. OXIDES.

(*a.*) *The protoxide* is formed by the action of water, the air being excluded; in that case, there is great effervescence, but no flame; 40 grains of potassium decompose 9 grs. of water and evolve 1 gr. of hydrogen gas, while the other 8 grs. combine with the metal; thence the quantity of oxygen is inferred; also, from the oxygen absorbed by potassium when it is exposed to dry air;† if it is in thin slices, the protoxide is formed in this manner also.

Proportions, potassium, 83.34, oxygen, 16.66=100.00.

This being nearly in the proportion of 100 potassium to 20 oxygen, it follows, that 20 : 100::8 : 40; 8 being the representative number of oxygen, 40 becomes that of potassium, and therefore the number for protoxide of potassium is 48.

---

* Graham, and Bib. Univ. XXII, 36.

† According to Thenard, it is the only metal that is acted upon by perfectly dry oxygen gas.

(*b.*) *Properties of the protoxide*, free from water; this is its condition when it is formed in dry air or in dry oxygen gas. It is white, very caustic, and fusible a little above a red heat, but it requires a very high heat to volatilize it.

Dissolved in water and obtained again, it becomes even after ignition, a hydrate, containing protoxide of potassium, 84, water, 16=100.

Potassium being represented by 40, oxygen by 8, and water by 9, it follows that the equivalent of hydrate of potassa is 57. This is the substance described under potassa. We know not whether the solid anhydrous protoxide is caustic or not, because its properties cannot be examined in this particular, without admitting water to it, when it becomes a hydrate. It has already been observed, that the hydrate melts at a low heat, (360°,) and is easily volatilized. The protoxide is formed also by acting on potassium with a small quantity of water, or by heating potassium with common caustic potassa, and by igniting potash in a crucible of gold.

(C.) PEROXIDE.

(*a.*) *The white dry protoxide heated in oxygen gas, absorbs two additional proportions, and becomes of an orange color.*—It may be formed also by heating and burning potassium in oxygen gas, or in common air.

(*b.*) *Its properties.*—Color yellow; fusible with less heat than hydrate of potassa, and crystallizes in laminæ by cooling. When plunged into water, the two additional proportions of oxygen are evolved, and it becomes hydrate of potassa. Heat greater than that at which it was formed, expels the excess of oxygen, and brings it to the state of *protoxide* or true anhydrous potash.* The heating must be performed in a platinum tray, and the oxide covered with muriate of potash. When mixed with combustible bodies, and heated, it acts vigorously upon them in consequence of the two additional proportions of oxygen which it contains, and it thus becomes potassa. The composition of the peroxide is potassium, one proportion 40, and oxygen 3=24, and its equivalent number is 64.

Nitrogen and potassium have no action upon each other, but if potassium be heated in ammoniacal gas, a fusible olive colored compound is formed, which consists of nitrogen and potassium, and of this compound and ammonia, and at the same time, hydrogen gas is liberated. As it appears not to be particularly important, we refer for a more full account of its properties to Thenard, Vol. II, p. 413, 4th Ed.

---

* This is said to be so fixed as to sustain the heat of a wind furnace without being volatilized; it attracts water very powerfully, and generates intense heat during its solution. The hydrate of the protoxide is easily volatilized by heat.

6. MISCELLANEOUS PHENOMENA.

(*a.*) *When thrown upon water, potassium floats, melts, becomes a polished sphere, runs briskly about, takes fires, and emits brilliant white red, and violet light*, with fumes of caustic potash; sometimes rings of white smoke, from the combustion of potassuretted hydrogen are formed in the air, and the regenerated alkali, by becoming red hot, often produces a slight explosion; if the piece is as large as a pea, the explosion is sometimes violent, and jets of the burning metal are thrown about the room, followed by white streaks of caustic potash.

The moving power that impels the floating metal, is potassuretted hydrogen gas, aided by steam, both being generated beneath the globule; the explosion is caused by the ignited caustic potash, combining with the water.

(*b.*) *On ice, potassium acts in a similar manner;* it burns and melts a hole, in which, the existence of a solution of caustic potash is easily ascertained by turmeric paper; it sometimes explodes on ice.

(*c.*) *Placed on ignited iron, it burns in common air, and brilliantly in oxygen gas*, producing abundant white alkaline fumes, which are soon condensed on the interior of the glass vessel.

(*d.*) *On all the test fluids—cabbage, turmeric, alkanet, &c. it burns and produces the effect of an alkali*, and that although they may have been first changed red by an acid: the experiment is strikingly exhibited in a small glass-flask, containing the watery solution of these colors.

(*e.*) *It flames on the three strong minerals acids*, producing with them salts of the respective acids: the sulphate of potash, on account of its insolubility, sinks through the fluid in white streaks.

(*f.*) *It dances about on alcohol and ether*, gradually wasting away, but generally without flaming, and the globule looks like polished silver: in the very best ether it sinks, and when it rises it does not of course prove that it is lighter than the ether, as it is often made buoyant by the hydrogen generated beneath it. It discovers and decomposes even the small quantities of water contained in alcohol and ether, and being insoluble in the latter, it forms in it, a turbid cloud of potash, while hydrogen is disengaged.

(*g.*) *With oils it slowly forms soap*, and when kept even under naptha, in vials carelessly closed, it, in the course of some time, becomes entirely saponified; absorbing oxygen first to form alkali, and this uniting with the naptha to form soap. Potassium, when heated in the concrete oils, (tallow, spermaceti, wax, &c.) acquires oxygen even from them, gas rises, the base is slowly converted into potash, and a soap is formed.

(*h.*) On test papers, if moist, it runs about, changes the color, and fires if there be moisture enough. We should never touch it with moist hands, as it immediately blazes, and we have in that case, both the actual and potential cautery.

(*i.*) *Hydrogen gas, heated in contact with potassium, dissolves it*, and becomes spontaneously inflammable, but loses this property by standing, and deposits potassium again. A solid compound of potassium and hydrogen, is formed by heating the gas and metal together, with a spirit lamp. It is gray, dull, infusible, and not inflammable, except at a high heat, when it burns vividly.

7. POWERS OF COMBINATION.

They are almost universal, as will appear farther on; it unites with iodine, chlorine, the metals and most of the combustibles, &c. and it decomposes the acids, most of the oxides and salts, and animal and vegetable bodies, and few substances, simple or compound, are unaffected by it. Its greatest prerogative however is to attract oxygen, which it takes from every thing, even from glass and stones, and from the firmest compounds, both natural and artificial.

8. *In relation to the state of our knowledge, it is an element.*—The most singular circumstance in the character of potassium is its levity: it resembles the metals very much in the greater number of its properties, but differs from them remarkably in specific gravity, while in its extreme inflammability it is assimilated to the most combustible bodies.*

9. POLARITY AND COMBINING PROPORTION.

Like other inflammable and metallic bodies, it resorts to the negative pole in the galvanic circuit, and is therefore electro-positive. Its combining number or chemical equivalent has already been stated to be 40, hydrogen being 1.†

10. USES.—As yet they are exclusively philosophical. In the hands of the chemist, it is a fine instrument of analysis, especially in the agencies which it exerts upon oxygen. It is a splendid substance for experiment, admitting of many beautiful and instructive modes of exhibition. From the improved modes of obtaining it which have been discovered, there seems little reason to doubt that it may be manufactured to any extent that may be required, and its introduction as a new means of annoyance and destruction, would perhaps not be improbable, were it not that it might prove nearly equally dangerous to friend and foe.

---

* These properties, with the remarkable fact, that during the galvanic decomposition of the alkali, although oxygen is evolved at the positive pole there is no hydrogen given off at the negative, led to the presumption that potassa is not a compound of oxygen and potassium, but of potash and hydrogen; the oxygen arising from the decomposition of water, and the hydrogen of that fluid going into union with the alkali to produce potassium. For an ingenious discussion of these and some other similar views, see Murray, 6th ed. Vol. II, p. 27.

† Mr. Murray has stated some reasons why it may rather be supposed to be 41, see as above.

Sec. III.—Soda.

1. Names.—The caustic soda was always, and is still unknown to commerce; anciently, the carbonate was called natron, natrum and nitrum, whence the nitre of the Scriptures. It is mentioned in the Bible, as a detergent, and as disagreeing (effervescing ?) with vinegar; both of which qualities belong to the carbonate of soda, but neither of them to nitre. In Africa, they call it trona; on the shores of the Mediterranean, soda and barilla. It has been called marine and mineral alkali. The term soda is now universally used.

2. History.—Indicated by Geber, an Arabian chemist, in the ninth century, but confounded with potash till after the middle of the last century; and unknown in its pure state until the discovery of the carbonic acid. Effervescence with acids was formerly considered as characteristic of soda as well as of the other alkalies, but it belongs to them in the state of carbonate only, and not in the pure state.

3. Points of similarity between it and potassa.

(*a.*) Their history is so nearly the same, that it is necessary only to indicate the difference.

(*b.*) All that respects the preparation is identical, and their properties are very similar.

4. Soda originates from *maratime and marine plants, the algæ fuci, salsola soda, &c.: the plants are dried, burned and lixiviated, and the lixivium evaporated to dryness. The crude soda of commerce, called barilla, is the incinerated salsola soda: kelp, a coarser variety, is the incinerated sea weed, and often contains only from 2 to 5 per cent of alkali; white good barilla contains 20 per cent. The crystallized carbonate of soda of commerce is obtained either from the calcination of the sulphate with charcoal and chalk in a reverberatory furnace, or by decomposing the muriate of soda by carbonate of potash.—*Ure.*

5. Properties.

(*a.*) *Caustic soda is at first deliquescent in the air, like potassa,* but unlike that alkali it never runs into the consistency of an oily fluid; for it soon becomes efflorescent, from combination with the carbonic acid contained in the atmosphere: a change which potash never undergoes.

(*b.*) Caustic soda is in the form of gray sub-crystalline masses, which can scarcely be distinguished from potassa, by the eye or by any sensible properties.

6. *The force of attraction in soda for the acids, is inferior to that of potassa:* the soda salts are decomposed by potassa.

---

* Salsola is a maratime plant, (i. e. it grows on the sea shore,) but the algæ are marine; the carbonate of soda of truly marine plants only, yields iodine.—J. T.

7. *Soda with oil forms hard soap—potash soft;* and soda is perhaps a little less caustic than potassa.

8. *Distinctive characters.*

(*a.*) It forms different combinations with acids; for instance, the sulphate of soda is very soluble in water; that of potash the opposite.

(*b.*) Its salts, suspended upon platinum wire, impart a rich yellow color to the blowpipe flame.—*Turner.*

(*c.*) Muriate of platinum and tartaric acid give no precipitates with salts of soda: the opposite is true of potash.

9. Uses and importance.—Soda is scarcely inferior in this respect to potassa: in soap and glass making it is largely used, and it is preferred for the finest articles. In the form of carbonate it is much used in medicine as an antacid: in medicine the caustic soda, is not used, having no advantage over potash.

10. *The distinction of vegetable and mineral* alkali is unfounded;* for both are found in plants, and both also in stones and various minerals. Still it is true that potash is found in most plants, and soda in those only which are connected with saline sources; on the other hand, solid mineral salt, the ocean and other saline waters, and the soda lakes and incrustations, present great quantities of that alkali in the mineral kingdom.†

11. Polarity.—In the galvanic circuit, soda goes to the negative pole, and is therefore electro-positive. Its combining weight is 32.

Remarks.—In commerce, we never see caustic soda; in its purest form, in the shops, it is always in semi-crystalline masses of carbonate, called sal soda.

The purest fossil alkali, obtained from the efflorvescence on plaster walls, contains about 60½ of its weight of alkali in crystals.

Alkali manufactured at Liverpool, - - - -	49
Fossil alkali from India, - - - - -	28
Best Alicant Barilla, - - - - -	26½
Sicilian Barilla, - - - - - -	23
The richest Kelp, made in Norway, the Orkney Islands, and Skye, - - - - - -	6½
The general produce of Scottish Kelp, - -	2½‡

There are associated with the soda in sea-weed, muriate and sulphate of soda, hydriodate of potash, or soda, and portions of lime, magnesia, silica, and alumina. There is also more or less of sulphur, which is often to a degree separated by the efflorescence of the soda,* in the form of carbonate.

---

* Potash was formerly called the vegetable alkali, and soda the mineral.

† As felspar, which constitutes so large a proportion of granite, whose detritus forms a considerable part of our soils, contains, on an average, at least 10 per cent. of potassa, this alkali may after all be more abundant than soda.—J. T. and C. U. S.

‡ Black's Lect.

When soda plants are made to vegetate away from saline sources, the quantity of soda constantly diminishes, and eventually they afford only potash.—*Murray*. Although soda is separated from its combinations with acids by potash, it exceeds that alkali in its power of neutralizing acids, in the proportion of 4 to 6, or 2 to 3, its equivalent being 32, and that of potash 48.

Mode of ascertaining the proportion of real alkali in the soda of Commerce.

Take sulphuric acid of the specific gravity of 1.10, which is generally prepared by mixing one part, by weight, of the best acid of the shops, with six of water.

Pulverize finely, an average sample; take, say 100 grains, and add to it 2 oz. measures of pure water, agitating it occasionally, for a few hours; after subsidence, decant, add more water, and again allow the solid matter to subside; decant again, and filter the fluids, and lastly, wash the solid residuum on a filter, until the water drops tasteless, and no longer affects the test colors. Mix the different fluids, and concentrate them, by boiling, to the volume of 2 or 3 oz. measures. In a vial of known weight, place 2 oz. of the acid, sp. gr. 1.10, and then add it cautiously to the alkali, till effervescence ceases, and the test papers are no longer altered. Sulphur will be precipitated. Now see how much acid remains. It having been ascertained by previous trials, that 100 grains of dry alcoholic potassa, require 520 grains of the acid, of the sp. gr. 1.10, for saturation, and that 100 grains of alcoholic soda require 812 grains of the same acid, it is easily calculated how much real alkali there was in the portion subjected to examination. Trial is made also, for potash, and the test used is muriate of platinum; there will be a yellow precipitate if potash is present; otherwise none. If muriate of potash should be suspected, since the muriate of platinum detects all the salts of potash, it may be known by adding a little sulphuric acid to the alkaline lixivium, when there will be fumes of muriatic acid gas, if the muriate of potash is present.†

SODIUM.

1. Discovery.—By Sir H. Davy, at the same time with potassium, October, 1807.

---

* Mr. Parkes, in his essays, mentions that some dealers refuse to buy the effloresced carbonate of soda, thinking it to be spoiled, whereas it is really in a good degree purified.

† Parkes' Chem. Essays, Vol. II.

2. Modes of obtaining.—The same as those described for potassium; only the decomposition of soda is more difficult, requiring a higher voltaic power, and in the process by the furnace, a greater degree of heat; a mixture of potash and soda is more easily decomposed, and affords an alloy of the two metals.

Dry muriate of soda or chloride of sodium is decomposed by potassium, with the aid of heat, and sodium is evolved; it is done in an iron tube.

3. Properties.

(a.) *Extremely similar to those of potassium.*

(b.) *Rather more solid at the common temperature*—under naptha, brilliant like silver, and quite as white.

(c.) *Very malleable;* by pressure of a platina blade, a globule $\frac{1}{10}$ or $\frac{1}{12}$ of an inch in diameter, is made to cover $\frac{1}{4}$ of a square inch, and this property does not diminish even when it is cooled down to 32°.

(d.) *Several globules, by strong pressure, unite into one*, and it is therefore capable of being welded at the common temperature, while iron and platinum require full ignition.

(e.) *It merely floats on water;* the sp. gr. at 59° Fahr. is supposed to be 0.972, water being 1.

(f.) *Less fusible than potassium;* softens at 120°, is perfectly fluid at 180° or 200°, and readily melts under naptha.

(g.) *Vaporizable*, but at what exact temperature is unknown, for it does not rise in vapor at the fusing point of plate glass, but is distilled at an intense heat.

(h.) *Tarnished by common air*, but not by air artificially dried, unless heated in it.

(i.) *Heated to fusion, it burns with scintillations and white flame.*

(j.) *On water, it melts, appears like a globule of floating silver, and wastes rapidly away*, but without emitting light, unless the water be hot, when it scintillates and flames; there is no combination of the sodium with the hydrogen evolved by the decomposition of the water, on the surface of which it has a rapid motion, owing to the causes mentioned under potassium. It burns in chlorine gas with bright red scintillations, and muriate of soda is the result. When plunged beneath it, it decomposes water with violent effervescence, and a loud hissing noise; soda is formed, and hydrogen evolved, but there is no luminous appearance. On moistened paper, or in contact with a small globule of water, as there is nothing to carry off the heat, the sodium usually inflames. The action on alcohol and ether, is the same as that of potassium. In the action of sodium on the oils, and on naptha, on sulphur, and phosphorus, on mercury and several other metals, there is almost a perfect similarity with the action of potassium. The soaps are of a darker color, and less soluble; the combination with sulphur, (effected as in the case of potassium in close vessels filled with the vapor of naptha,) is attended with very vivid light, and much heat, and often explosion. The amalgam of mercury and sodium seems to form triple compounds with other metals; Sir H. Davy thought that the mercury remained in combination with iron and platinum, after the sodium was alkalized, and separated by deliquescence. The amalgam forms a triple compound of a dark gray color with sulphur.

(*k.*) *Inflames on the strong acids*, forming salts with soda for a basis; the nitric acid, as usual, acts with the most energy.

4. Oxides.

(*a.*) *Protoxide.*—Sodium combines spontaneously with oxygen reproducing soda,* but its attraction for oxygen appears to be less energetic than that of potassium; the process is slower, and the deliquescence of the alkali produced is not so rapid. The combination is accelerated by heat, but combustion in oxygen gas does not take place till near ignition; it then burns beautifully with a white flame and bright sparks, and, in common air, the flame is similar to that from burning charcoal, but much brighter. Sodium heated with soda, is said to divide the oxygen between them, producing a deep brown fluid, which, on cooling, becomes a dark gray solid, and attracts oxygen again from air and water.†

The protoxide is produced also by burning sodium in dry common air, the sodium being in excess, or by the action of water. This protoxide is caustic soda; its color is gray, fracture vitreous, does not conduct electricity, fusible at a red heat, combines with water, with great heat, and produces hydrate of soda, which is white, crystalline and more fusible and volatile than before. Its constitution is,

1 proportion of sodium, - - - - -	24
1 " oxygen, - - - - -	8
And the equivalent of anhydrous soda is	32

It combines with water, as already remarked, with great energy, becoming a hydrate, and the water cannot be expelled by ignition. The constitution of the hydrate,

1 proportion of protoxide,	32	per cent. 22½ water.‡
1 " water,	9	
	41	

(*b.*) *Deutoxide of sodium.*—Burn sodium in an excess of oxygen gas, or heat the protoxide in that gas; the protoxide is always formed first, and then more oxygen is absorbed, and the peroxide is generated. The color of this oxide is yellowish green or orange; it is fusible; a non-conductor of electricity, and when thrown into water, it gives out its excess of oxygen.

---

* This happens, of course, if it is not carefully kept; I have lost masses of sodium in this manner; the metal turns into white caustic soda, and eventually effloresces in the form of carbonate, at the same time enlarging its volume very much.

† It is doubted whether it is not a mixture of the metal with soda.

‡ See Mr. Dalton's table of the quantities of soda, in different solutions, Henry, Vol. I, p. 558, 10th Lon. Ed.

Its composition according to Davy, is	
sodium, -	75
oxygen, -	25
	100

Its constitution is stated to be 1 proportion of sodium 24, and 1½ of oxygen =12=36, but as this introduces a fraction, it is probable that our knowledge is not precise.

The peroxide acts upon most combustible bodies with deflagration. According to some, the peroxide is composed of two proportions, of

Sodium, - - - - - - - -	48
Oxygen 3, - - - - - - -	=24
	72

would then be its equivalent or representative number; of the truth of this view, there seems to be no direct proof.

5. Powers of combination.

They are very extensive, like those of potassium; to which however it yields an energy of affinity, as is evident in the case of the decomposition of common salt by potassium.

6. Polarity.

Like potassium, it is attracted to the negative pole in the galvanic series, and in this way it was first discovered.

7. Diffusion.

Sodium exists very extensively in the carbonate, sulphate, muriate and other forms of soda salts; it is found in some plants, especially marine ones, and in many stones and rocks.

Remarks.—The great prerogative of sodium is to attract oxygen, in which function, it is inferior only to potassium. Both these remarkable bodies are endued with such a degree of activity, and their chemical relations, are so numerous, as almost to realize the brilliant suggestion of their illustrious discover,* that they approach to the character of the imaginary alkahest of the ancient alchemists. Their discovery has placed in our hands new means of investigation, and of beautiful and splendid experiment. Nothing could be more unexpected, than that common salt and sea weed should contain a metal, or wood ashes another. In the present state of our knowledge, we must regard potassium and sodium as elements. As they exist abundantly in minerals, we can understand how, in the processes of vegetable life, they should become constituent parts of plants. It has been already stated, that hydrogen has been supposed by some, to be one of their constituent principles; a suggestion which is countenanced by their levity, and by the fact, so contrary to what is found to be true in most other cases, that their oxides are heavier than the metals which they contain.*

---

* Applied by him more particularly to potassium.

Sec. IV.—Lithia.

1. Name.—From λιθος, a stone, or λιθειος, stony.

2. Discovery.

Detected in the year 1818, by Mr. Arfwedson, in the petalite, which contains from 3 to 8 per cent.; in the triphane or spodumene,† there is 8 per cent. and in crystallized lepedolite, 4 per cent.; it has been found also in the green and red tourmaline, and in several varieties of mica.

3. Process.

(*a*.) Fuse the powdered petalite, 1 part, with carbonate of potash 3 parts, dissolve in muriatic acid—evaporate to dryness—digest in alcohol, which takes up the muriate of lithia and little else; this solution is evaporated to dryness, and the residuum again dissolved in alcohol, which gives the muriate pure; it is then digested with carbonate of silver, to form carbonate of lithia; this being decomposed by lime or barytes, gives pure lithia, which must be evaporated to dryness, away from the air.‡

(*b*.) Another process by Berzelius, is as follows:—Mix 2 parts of fluor spar, and 3 or 4 of sulphuric acid, with 1 of powdered petalite or spodumene, and apply heat till the acid vapors, consisting principally of silicated fluoric acid, have ceased; thus the silica is removed, and the alumina and lithia unite with the sulphuric acid, in the form of sulphate; that of alumina is decomposed, and the earth precipitated by boiling with pure ammonia. Ignition expels the sulphate of ammonia, and the pure sulphate of lithia remains, which is easily converted into the carbonate, and the carbonic acid being expelled from this, we obtain the pure lithia.

---

* It is however sufficient to caution us against admitting conjectures in such cases, that soda was formerly suspected to be composed of magnesia and nitrogen, and Fourcroy, in his large work, has stated the reasons why he with some other chemists, conjectured that potash was composed of lime and nitrogen, and soda of magnesia and nitrogen.

† In the spodumene and petalite, the lithia is combined with silica and alumina; but in the lepidolite and in the lithion mica, it is combined also with potassa, and to avoid contamination with this alkali, the lithia should be prepared from the spodumene and petalite.—*Turner*.

‡ For other processes, see Ann. de Chim. et de Phys. X. 86; also, Henry, Vol. I, p. 572, and Thénard, Vol. II, p. 323, 4th Ed.; Ure's Dict. 3d Ed. p. 582.

4. PROPERTIES.

(*a.*) Color white; not deliquescent, but absorbs carbonic acid by exposure to the air, and becomes a carbonate.

(*b.*) Very soluble in water, but less so than potassa and soda, and scarcely soluble at all in alcohol; acrid, caustic, acts on colors as the other alkalies do.

(*c.*) Heated with platinum, it acts on the metal; place on platinum foil, with a small excess of soda, a piece of a lithia mineral as large as a pin's head, and heat it with the blowpipe for two minutes; a dark color or dull yellow trace appears near the fused alkali, and the metal is oxidized by aid of the lithia and the air, while it is not affected under the soda. The soda, by combining with the other principles of the stone, liberates the lithia.

(*d.*) Lithia has a higher neutralizing power than potassa and soda, or even than magnesia; its phosphate and carbonate are sparingly soluble, its chloride is deliquescent and soluble in alcohol, and this solution burns with a red flame; all the salts of lithia give a red color when heated on a platinum wire before the blowpipe. "Lithia is distinguished from the alkaline earths by forming soluble salts with sulphuric and oxalic acids," and the carbonate,* although difficultly soluble in water, stains turmeric paper brown. The muriate and nitrate are deliquescent; the concentrated lithia salts mixed with a strong solution of carbonate of soda, deposit carbonate of lithia.—*Berzelius.*

Some of these properties have been mentioned in anticipation, and others are omitted or reserved for their more appropriate place.

5. DECOMPOSITION.

The metallic base was evolved by Sir H. Davy, by galvanism, but it was too rapidly oxidized to be collected; and the metal was, however seen to be white like sodium, and burned with bright scintillations. Composition supposed to be—lithium, 56.50, oxygen, 43.50 = 100.00, or by Dr. Thomson, lithium 10, which he supposes to be its equivalent number, and oxygen 1 proportion 8=18, for the equivalent of the alkali.

---

* Like the earthy carbonates, and it therefore forms an exception to the general characters, stated p. 230, (*d.*)

EARTHS.

LIME—BARYTA—STRONTIA—MAGNESIA—SILICA—ALUMINA—GLUCINA—ZIRCONIA AND YTTRIA.

Introductory Remarks.

In the plan of this work, and in connexion with the alkalies, some objections have been stated to the prevailing mode of arranging most of them, and all the earths, under the metals. With respect to the earths, this course, though highly inconvenient, would perhaps be somewhat less so than in relation to the alkalies; but I decidedly prefer to preserve the old division of earths, notwithstanding the interesting discovery that most, if not all,* of them are metallic oxides. Here, as in the case of the fixed alkalies, there can be no difficulty in pursuing the analytical course, by proceeding from the compound to its principles,—first describing the earth, and then its composition; and reverting again to the metallic bases of the earths, when we come to the metals. The great advantage proposed in pursuing this course is, that we are, as early as possible, put in possession of a knowledge of the properties of these important bodies, and that the natural order of earths will remain unbroken; for, as Dr. Ure (Dict.) very justly remarks, "whatever may be the revolutions of chemical nomenclature, mankind will never cease to consider as earths, those solid bodies composing the mineral strata, which are incombustible, colorless, not convertible into metals by all the ordinary methods of reduction, or when reduced by scientific refinements, possessing but an evanescent metallic existence, and which either alone, or at least when combined with carbonic acid, are insipid, and insoluble in water."

Nearly the whole crust of our planet is composed of these bodies; for, the combustibles, and alkalies, and the metals, properly so called, form but a very small proportion of the whole. Nine bodies have been distinguished by chemists, to which the name earth has been given; they are, as enumerated at the head of this division, Lime, Baryta, Strontia, Magnesia, Silica, Alumina, Glucina, Zirconia, and Yttria.

The three latter are of little consequence, either in a scientific or practical view, and seem chiefly important in determining the constitution of some few gems, and of a few other minerals, most of them rare. Of the remaining six, the most abundant is silica; lime, is in this respect, the next; then follows alumina, and then magnesia;

---

* The base of silica seems to have no claim to be called a metal; should it be melted it may, perhaps, exhibit metallic properties.

these four earths constitute the great mass of our mountains, rocks, stones, gravel, and soil, and were the five others annihilated, it would not sensibly diminish the volume of the crust of the globe. Baryta and strontia exist, however, in some quantity, and baryta, especially combined with sulphuric acid, is of frequent occurrence, although it is generally confined to veins in the rocks.

As chemical reagents, lime and baryta are of signal utility; strontia possesses similar properties, but has, in comparison with those earths, little that is peculiar, or that gives it a ground of preference. Silica, alumina, and magnesia are of limited use in scientific chemistry, but they are of vast importance in the arts, and along with lime, are the foundation of the vegetable kingdom, and of agriculture; as our best soils consist of different proportions of these earths; and the varying qualities of soils, although modified in an important degree by moisture and by animal and vegetable matter, and other causes, are characterized chiefly by the predominant earths.

The preceding sketch has been presented, that the student might not fail to obtain a just idea of the important natural order of earths, which it is difficult to define by unexceptionable chemical characters; but there is no difficulty in giving clear discriminations, provided we divide the earths into groups.[*]

The divisions under which the earths will be described, are—

1. Alkaline earths.
2. One earth of a sub-alkaline character.
3. Earths proper.

ALKALINE EARTHS.

LIME—BARYTES—STRONTIA.—THEIR GENERAL CHARACTERS.

(*a.*) *Soluble in water*, but much less so than the alkalies.

(*b.*) Acrid and caustic; in light powder, irritate the nostrils, and produce sneezing.

(*c.*) Test colors affected by them, as by the alkalies.

(*d.*) Differ from the alkalies in their very difficult fusibility, but fusible by the compound blowpipe, and by galvanism.

---

[*] Perhaps the only characters that will strictly apply to them all, are these—1. They are, when prepared pure by art, white powders.—2. They are not volatile by heat, and are remarkably difficult to melt, and are, both when pure, and when in combination with each other, in the stones and rocks, the most infusible and unalterable bodies that are generally known to mankind.—3. They have oxygen for a common principle, united, in each earth, to a peculiar metallic or combustible base. It is true (as suggested by a friend,) that some of the proper metallic oxides, would be covered by these characters, e. g. the oxides of columbium, titanium and cerium; but still, most of our artificial divisions, fail of rigorous exactness; the oxides themselves graduate into the acids, but no one for that reason thinks, of blending them. There can be no good objection to dividing the numerous class of oxides into convenient orders, which are also in a great measure natural. See Introduction, p. 2.

(*e.*) Not volatile by any heat hitherto applied.
(*f.*) Form soaps with oils.
(*g.*) In common with the other earths, combine with acids and form salts.*

EARTH OF A MIXED CHARACTER.—NAMELY, MAGNESIA.

(*a.*) Not acrid or caustic.
(*b.*) Applied in substance, affects the vegetable colors.
(*c.*) Nearly insoluble in water, but absorbs it.
(*d.*) Equally difficult to fuse as lime, not volatile.
(*e.*) Combines readily with acids to form salts.
(*f.*) Combines indirectly with oils to form soap.

EARTHS PROPER.—SILICA—ALUMINA—GLUCINA—ZIRCONIA—YTTRIA.†

Destitute of alkaline properties, except that

(*a.*) They unite with acids, and form salts; silica combines permanently with only one acid; i. e. the fluoric.
(*b.*) Insoluble in water; but most of them absorb it.
(*c.*) Tasteless, innoxious, inodorous.
(*d.*) No effect on test colors.
(*e.*) Very difficult to melt, but less so than the alkaline earths; still the alkaline earths are powerful fluxes of the earths proper, and of common metallic oxides.
(*f.*) Not volatile by heat.
(*g.*) In their pure state, do not combine with oils to form soap.

Sec. I.—Lime.

1. Discovery.—Familiarly known from the remotest ages.

2. Preparation.

(*a.*) By thoroughly igniting, in a good furnace, in a covered crucible, small fragments of marble, chalk,‡ or shells, or other pure calcareous carbonate of lime, (Carrara and Parian marble are preferred,) these substances lose half their weight or more in the form of gas and water, and if fully calcined, they will not effervesce with acids.

(*b.*) As the natural carbonates of lime are not always pure, we may dissolve them in dilute muriatic acid; then add ammonia, which will precipitate the magnesia and alumina, and not the lime; we then decompose the filtered solution by carbonate of potash, and the precipitated carbonate of lime, after being washed and dried, is decomposed by a strong heat. Common good quick lime, that has not been air slacked, answers every purpose for demonstrating the properties of lime.

---

* Even silica combines permanently with fluoric acid, and transiently and slightly with some other acids; this earth differs in several respects from the rest, and some have even regarded it as an acid.

† It is scarcely necessary to remark that Thorina, which was transiently admitted among the earths, has been found to be a sub-phosphate of Yttria.

‡ Chalk is the least pure of the three.

3. Properties.

(*a.*) *Color*, white, and the masses recently from the furnace are rather hard, but brittle. When dry, not active on the animal organs, but if moistened, lime acts as a caustic; taste astringent and alkaline.

(*b.*) Specific gravity 2.3.

(*c.*) *Soluble in water:* writers vary in stating the proportion, between 450 and 778 parts of water for the solution of 1 part of lime, or 558 for the hydrate: 500 is the number heretofore adopted; probably 700 may be near the truth; but it appears that only a weak lime water is obtained by using water at 212°, which dissolves only $\frac{1}{1270}$ of the lime, and $\frac{1}{952}$ of the hydrate, while at 32°. According to Mr. Dalton* and Mr. R. Phillips, it takes up $\frac{1}{656}$, or nearly double, and when the solution is heated, it becomes troubled, and lime is deposited. These facts are not in accordance with the general laws of solution when it is aided by heat.

(*d.*) *Lime water:* its taste is acrid and disagreeable, and it produces upon test colors the effects of alkalies; it is not however caustic, and there is so little of it contained in the water that it may be swallowed with safety, and often with advantage. It is a valuable reagent and medicine; it is prepared by simple solution of lime, in water; it must be preserved in close bottles from the atmosphere,† otherwise it precipitates as a carbonate.

(*e.*) *Lime water‡ is made to afford crystals*, if placed in a vacuum, under the receiver of an air pump, the evaporation being aided by sulphuric acid, contained in another vessel; the process is gradual, and depends on the same principle as the congelation of water by the same means, (see page 116.) The crystals are transparent hexahedra, and are true hydrates, containing lime, 76.26, water, 23.74=100.00.‡ Lime water forms an imperfect soap with oil.

---

* Ann. Phil. N. S. I. 107.

† Place in a clean carboy, a quantity of good hydrate of lime; fill the vessel with rain water; agitate it, and allow the lime to subside over night; it will be dissolved in one fourth of an hour, and in the morning it may be drawn off clear by a syphon, or filtered through paper if it is wanted immediately; if the cork be good, and the water is not allowed to freeze, the same arrangement, adding water from time to time, will answer for years.

‡ Ann. de Chim. et de Phys. I. 335.

(*f.*) *Slacking of lime.*—In this familiar process, the earth combines with about one third of its weight of water, forming a true hydrate; and in this condition, lime kept secluded from the air, is in the most useful state for the laboratory. The water may be again expelled by a red heat, contrary to the fact in the case of the hydrates of potassa and soda, and of baryta and strontia. The heat, (about 800°, Dalton,) arises from the solidification of the water, and is much more than the latent heat of the water, because ice or snow and lime slack, with energy, and give out a heat of 212°. Light sometimes appears, when the slacking is performed in a dark place; I have seen it from the Carrara marble.[*] If fragments of good lime be placed in a quart tumbler, filling not more than one third of it, the tumbler resting in a dish, the proper quantity of water being sprinkled over it, and a tall bell glass covering the whole, the vapor will rise in a dense cloud; it will soon produce currents like rain, down the sides of the bell, which will become clear, as soon as it attains the boiling heat, and the steam will then blow out powerfully under its sides: when the bell is lifted out of the dish, the cold air will again produce a thick cloud.

(*g.*) *Milk or cream of lime*, is the hydrate brought to the consistence of paste with water, and thus mechanically suspended: it is very useful in purifying gases from carbonic acid; they are, for this purpose, made to pass through the milk of lime, the large quantity of the earth being much more effectual than lime water, which is however, very convenient in small experiments.

(*h.*) *Lime is mechanically raised in slacking*, as is perceived by the odor, and by the effect on test paper, placed in the steam that rises from it.

(*i.*) *Lime absorbs moisture from the air*, falls to powder, and becomes a true hydrate.[†]

(*j.*) *The mere water-slacking of lime does not destroy its activity;* its peculiar powers are blunted or suspended by air-slacking, the cause of which will be explained under the history of the carbonate.

4. Fusibility.—*Extremely infusible;* first partially melted by Dr. Hare's compound blowpipe, in Philadelphia, and in 1812 more perfectly, in the laboratory of Yale College.[‡] The lime must be shaped into the form of an acute cone, not over the size of a large pin, and the focus of heat must be directed upon the apex; when it softens, subsides, and is soon covered with a vitreous glaze. Fusible also in the galvanic current. The light emitted by lime, in the focus of heat, is most intense; it has been used with a stream of oxygen gas,

---

[*] In a dark cellar, in Mr. Accum's house, in London, some lime of Carrara marble, during its slacking, showed luminous points of mild white light.

[†] It also absorbs carbonic acid, and loses its causticity.

[‡] Afterwards by Sir H. Davy, by Galvanism.

directed through the flame of an alcohol lamp, for the purpose of producing a signal light, which can be seen at a great distance.

5. **Polarity.**—It is attracted to the negative pole in the galvanic circuit, and is therefore electro-positive.

6. *Combining weight*, 28, as will be seen more particularly under calcium, the basis of lime.

7. **Pharmaceutical preparation.**—This is the same that has been already described in giving the process for quick lime.

CALCIUM.

1. **Discovery.**—In 1808, in Sweden, by Prof. Berzelius and Dr. Pontin; afterwards obtained by Sir H. Davy in England. Thénard attributes the first observation to Dr. Seebeck.

2. **Process.**

(*a.*) A cup or capsule, made of moistened lime, or sulphate of lime, containing a globule of mercury, is placed on a metallic dish; the negative wire of the galvanic battery of 100 pairs, in good action, is made to touch the mercury, and the positive wire is brought in contact with the under side of the metallic support. An amalgam of mercury and calcium is formed, but the process must be continued a good while in order to obtain any manageable quantity; in a small (green*) glass retort, or tube closed at one end, this amalgam is distilled, with naptha, which rises first, then the mercury, and the calcium remains in an atmosphere of vapor of naptha, for which nitrogen may be substituted.

(*b.*) When potassium, in vapor, was passed through quick lime heated to whiteness, the potassium acquired oxygen, and became potash, and a dark gray substance, with metallic lustre, was found imbedded in the potash, and it was evidently calcium, more or less perfectly reduced, because it effervesced violently in water, and formed a solution of lime.

3. **Peroxide.**—This is formed when oxygen gas is passed over lime ignited in a tube; the exact proportions are not known, but it is supposed to contain twice as much oxygen as the protoxide.

In the moist way, the oxygenized water of Thénard forms the same peroxide.

4. **Properties.**—*Little known.*

(*a.*) Color, white, like that of silver, and with the same lustre; sinks in water.

(*b.*) Ignited in a tube in which the distillation of the amalgam was going on, it took fire when the tube broke, and burnt with an intense white light, into quick lime. When the amalgam of calcium was thrown into water, hydrogen gas was evolved, and lime water remained.

---

* Because white glass contains oxide of lead, whose oxygen would change the calcium to the state of oxide, or lime.

(*c.*) Lime is the protoxide of calcium. Its composition is estimated by Berzelius at calcium, 71.73, oxygen, 28.27=100.00.

Thénard says, that it ought to contain by calculation, 39 of oxygen.

5. ITS EQUIVALENT WEIGHT is stated at 20, and therefore, oxygen being 8[*], lime, or the protoxide is represented by 28.

6. POLARITY.—Electro positive; it goes to the negative pole in the galvanic series.

7. USES OF LIME.—They are numerous and important. In medicine, the caustic earth is not used, except to prepare lime water; in the solid form, the pure earth is too acrid for internal use; it was formerly used as an escharotic, and its caustic properties are still employed in removing the hair from skins, preparatory to tanning. It is almost constantly used in the laboratory; in the form of lime water, it is an important reagent, and we have seen that it is employed to disengage the alkalies in a caustic state; it is largely used for the same purpose in soap making. In a word, it is of great value in medicine, in architecture, in agriculture, and in many arts.

Mortar is a mixture of sand, or gravel, or both and lime; in the proportions of fine sand 3 parts, coarse sand 4, quick lime 1, recently slacked with as little water as possible.

It is well to add some pulverized lime, that has not been slacked; it absorbs water, and solidifies the other ingredients. Roman mortar was made of the same materials as the modern, but of the best quality, and accurately proportioned; time has done much to give it hardness. According to Pliny, the Romans made their best cement a year before it was used, so that it was partly combined with carbonic acid before it was laid in the work. In old Roman stone buildings, the stone will often break as soon as the mortar.

Another recipe for mortar.—Fine sand, 3, brick powder, 3, (well baked,) slacked lime, 2, unslacked lime 2. If very little water be used, the mortar sets the sooner. Burnt bones, not exceeding one fourth part, improve the tenacity of mortar.

Manganese and puzzolana cause mortar to harden beneath the water. Puzzolana is decomposed lava, and consists of silica, alumina, and oxide of iron. The mortar for the Eddystone light-house on the S. W. coast of Cornwall, (Eng.) was composed of equal parts of slacked lime and puzzolana.

---

[*] For 71.73 : 28.27 :: 100 : 39.4 and 39.4 : 100 :: 8 : 20.3.—*Henry.*

Manganesian and ferruginous limestones are valuable in this respect, and a portion of silica and alumine in the composition of the limestone improves it for these purposes.[*]

Recipe for water mortar.[†]—Blue clay, 4 parts, manganese, 6, limestone 90, and all in powder; calcine, mix with sand 60 parts, and form it into a mortar, with water. The tarras,[‡] used for the construction of dykes in Holland, is merely an ancient decomposed lava from the extinct volcanos on the Rhine; some call it a decomposed basalt, and it is certain that the rocks of this family, are effectual in this way, if previously decomposed, or calcined, so that they can be broken down and intimately mixed with the lime.[§] Parker's cement is composed of silica, 22, alumine, 9, oxide of iron and manganese, 13, carbonate of lime, 55=99, and there was in the analysis a loss of 3.25. The white cement used in New Haven to cover stone houses, is composed of the best slacked lime, 1 part, by measure, and from 3 to 5 measures of coarse siliceous sand and some hair, well beaten together, and laid on with a trowel; the workmen pretend to add sugar, and various salts, particularly the sulphate of potash; but having tried the mortar, both with and without these additions, I am persuaded that they are of no importance, and that the cement of coarse sand, hair and lime, alone, will stand any length of time, provided water does not get beneath; if it does, the first freezing will crack the mortar, and throw it off.

Lime is of great use in Agriculture.—In the form of carbonate of lime, it is often mixed with soils, and will be mentioned again. In the state of quick lime it is largely used in England, where it is common to see extensive tracts covered with heaps of it.[||] It appears to be a part of the food of plants, as it is found in the ashes of most of them, and it may be also a stimulus to vegetable life. Its immediate action, when caustic, is to destroy vegetable organization, and it appears to act as a manure, principally by decomposing hard dry vegetable fibres, and thus rendering them soluble; even tanner's bark is decomposed by lime, and rendered useful as a manure; it is thought to be injurious with animal manures, unless they are too rich, and need to be in part decomposed.*

---

[*] Hydraulic lime of the state of New York, contains according to Dr. Hadley's analysis, carbonic acid 35.05, lime 25, silex 15.05, alumine 16.05, water 5.03, oxide of iron 2.02.—*Am. Jour. Vol. III, p.* 231.

[†] Hydraulic lime is found at Southington, Connecticut, near the canal, and in many places on the Erie Canal.—See Am. Jour. Vol XIII, p. 382.

[‡] The proportions said to be used in Holland, are tarras 1 part, and slacked lime 2 parts.

[§] I saw them preparing the trap rocks in this manner, at Greenock, where (1806,) they were making hydraulic mortar for a dock. The porous and vesicular trap which they used was from the neighboring isle of Arran. That in East Haven, which is crumbly, and used for mending the roads, and the vesicular trap near Hartford, (see Am. Jour. Vol. XVII, No. 1,) would in all probability answer the same purpose, and it may be found of the same character in many other places in our trap regions. The more vesicular, and the more decomposed it is, the better, because it is the more easily pulverized by calcination and grinding.

[||] Extensively used in Pennsylvania, and highly valued.—J. G. Not much used in New England.

SEC. II. BARYTA.

Name from the Greek βαρὺς, heavy.†

1. DISCOVERY.—By Scheele, in Sweden, in 1774; formerly confounded with lime.

2. PROCESS.

(*a*.) Native, or artificial carbonate, in powder, mixed with lamp-black and oil, in a ball, is strongly calcined in a crucible, for one hour, by the heat of a forge or wind furnace, and the carbonic acid is thus decomposed, or, expelled. Boiling water dissolves out the caustic earth. The theory of the process will be rendered more intelligible hereafter.

(*b*.) By calcination of the nitrate of Barytes; see that salt.

3. PROPERTIES.

(*a*.) Color, gray before slacking; consistency, porous; after slacking, a white powder; sp. gr. 4.

(*b*.) Taste acrid and caustic; poisonous.

(*c*.) Affects the test colors, as lime and the alkalies do.

(*d*.) *The hydrate is fusible* in its own water, of which it contains about 9 or 10 per cent.

(*e*.) Baryta, even when obtained from the nitrate, is fusible by the compound blowpipe.‡

(*f*.) *Water causes it to slack* with much greater energy than lime; the phenomena and theory are the same, but much more striking, and light is said to be sometimes emitted.§ The water slacked baryta, is a true hydrate, and as the earth is represented by 78, and there is one proportion of water in the hydrate, the equivalent number is of course 87.

(*g*.) *It slacks in the air*, as lime does, and for the same reason.

(*h*.) *It dissolves readily in* 20 *parts of water at* 60°, and if boiling, in 2 parts.

(*i*.) *On cooling, it forms regular crystals*—flattened hexagonal prisms.

---

* See Davy's Agricultural Chemistry, and Ure's Dict.

† The natural sulphate is known to the miners, by the name of heavy spar.

‡ Respectable authors state that *baryta thus prepared is infusible*, but they had probably not tried the compound blow-pipe.

§ The observation is attributed to Dobereiner, and it will not appear very extraordinary, since lime sometimes exhibits light while slacking, although the energy of the action is much less remarkable.

(*j.*) *They contain*, according to Dalton, 70 *per cent. of water*, and lose 50 by ignition; their constitution is, according to the same author, baryta 1 proportion 78, and water 20 proportions or 180, and their equivalent number is 258; they melt in their own water, or suffer the aqueous fusion; after ignition, the dry powder which remains, slacks again with great energy.

(*k.*) Crystals soluble in 17½ times their weight of water.

(*l.*) *Burning alcohol*, although it does not dissolve this earth, *receives from the crystals a yellow tinge*, but this is better exhibited in the flame of the compound blowpipe, in the focus of which, every form of baryta, not excepting the sulphate, exhibits this characteristic color in the most striking manner.

(*m.*) *Barytic water is a very useful reagent;* it should be kept stopped from the air, otherwise it is precipitated in the form of an insoluble carbonate. It produces all the effects of the alkalies upon the test colors.

(*n.*) *Solution of baryta forms a soap with oils;* its salts also form soaps if mingled with aqueous solutions of alkaline soaps.

(*o.*) Dust of the earth irritates the nostrils as it rises.

4. Polarity—electro-positive, it resorts to the negative pole of the galvanic battery.

5. Combining Weight, 78, the elements of which may be seen under barium.

BARIUM.

1. *Obtained in the same manner as calcium*, using native carbonate of baryta or the pure earth,[*] made into a paste with water, a globule of mercury being placed in a little hollow made in its surface; the paste was laid upon a platinum tray in connexion with the positive wire of a galvanic battery, while the negative wire touched the mercury. The mercury is distilled off in the same manner, but it is very difficult to obtain the metal.[†]

2. Properties.

(*a.*) *Metal of a dark grey color*,[‡] with less lustre than cast iron.

(*b.*) *Solid at the ordinary temperature*, but becomes fluid below ignition.

(*c.*) *Near redness, rises in vapor*, and acts violently on the glass.

---

[*] Oxide of mercury may be used in obtaining the metals of the earths; one third part is mixed with two thirds of the earth, and galvanized, when an amalgam is formed with the metallic base.

[†] Dr. Clarke states that he obtained the metal from the nitrate, by the compound blowpipe. I mentioned in the memoir published in Bruce's Journal, in 1812, that the metallic bases of both baryta and strontia, appeared to me to be evolved, and to dart out in bright scintillations, when the earths were in the focus of the instrument, but as they always burned away, I was not able to collect the metals.

[‡] "White color, with metallic lustre, having a resemblance to silver."—*Murray*.

(*d.*) *In air, becomes covered with a film of baryta*, and in water undergoes the same change; effervesces violently and evolves hydrogen. If gently heated in air, it burns with a deep red light and becomes baryta.

(*e.*) *Sinks in water, and even in sulphuric acid*, although surrounded by gas; hence its sp. gr. cannot be less than 2, probably over 3.

(*f.*) Flattened with difficulty by pressure.

(*g.*) *Constitution of the protoxide*, about 89.75, metal, 10.25 oxygen = 100.00. Barium, 1 proportion, 70, oxygen, 1 proportion, 8 = 78.

(*h.*) Peroxide or deutoxide.—Baryta, prepared by ignition of the nitrate, is placed in fragments as large as a hazel nut, in a coated glass tube, and heated to low redness, when it rapidly absorbs dry oxygen gas as it is passed over it and becomes peroxide with probably two proportions of oxygen; it is formed also by heating baryta in contact with oxygen or common air resting upon it, but in the latter case some carbonate is also formed. Concentrated barytic water becomes filled with pearly plates of the deutoxide of barium, when oxygenized water, containing ten or twelve times its volume of oxygen is poured into it.—*Thénard.*

Composition of the peroxide.—Barium, 70, oxygen, 2 proportions, 16 = 86; the peroxide contains twice as much oxygen as the protoxide.

It has been found that the nitrate of baryta may be decomposed by heat with such care, that the deutoxide is left; it is done in a luted porcelain retort, connected by a Welter's safety tube with an inverted jar of water. The heat is gradually raised to redness, as long as nitric oxide or nitrogen gas is disengaged, and when they cease and pure oxygen comes, it is a proof that all the nitrate is decomposed, and then the deutoxide will remain in the retort.—*Turner.*

(*i.*) The deutoxide of barium is scarcely sapid, it is grayish white, loses its excess of oxygen by an intense heat, and acts with the aid of the same agent upon various combustible bodies, and thus becomes a protoxide. In contact with hydrogen near a red heat, there are luminous jets from the surface of the deutoxide, but the water that is formed is all retained in the state of hydrate, and the baryta thus becomes very fusible. Boiling water causes the excess of oxygen to escape in the form of gas.

(*j.*) This substance was employed, (July, 1818,) by Thénard, for the oxygenation of water.*

Baryta is poisonous; its natural carbonate is employed in Lancashire, (Eng.) as a ratsbane.

---

* See this work, p. 215, and Henry, Vol. I, p. 264, 10th Lond. Ed.; also, Ann. de Chim. et de Phys. VII. IX; Ann. of Philos. XIII, XIV, XV, and Quarterly Eng. Jour. of Science, VI. 150, 379, VIII. 114, 154.

Pure baryta is useful to the chemist as a test, particularly for the discovery of carbonic acid, either free or combined. Its muriate is used by physicians in scrofula, &c. The sulphate is the most abundant form, and it is convertible into every other, by certain processes which will be mentioned in their proper place.

3. Polarity—*Electro-positive;* it resorts to the negative pole in the galvanic circuit.

4. Combining weight, 70.—This is the number of Dr. Thomson. Berzelius states it at 50.66, but the former number is generally adopted.

Sec. III.—Strontia.

1. Name.—From the lead mine of Strontian, in Argyleshire in Scotland, whence the minerals containing it were first brought.

2. Discovery.—By Dr. Thomas Hope,* then and still, professor of chemistry in the Univ. Edin. Anno. 1791.

3. Preparation.—The same as that of baryta.†

4. Properties.

(*a.*) The result of the igneous decomposition of the nitrate is a grayish porous substance; sp. gr. approaching that of baryta.

(*b.*) *With water, slacks violently,* like baryta and lime, and the theory is the same; the powder of the dry substance irritates the nostrils and lungs.

(*c.*) *After slacking,* no more water being used than is necessary, *the earth remains in the form of white powder;* it is then a hydrate consisting of strontia, one proportion, 52, and one of water 9=61. The hydrate fuses readily at ignition, but is not decomposed by the strongest heat of a wind furnace.

(*d.*) *More water being added, it dissolves* in about 40 parts; if the water be boiling hot, it dissolves in 20 parts of that fluid, and crystals are formed on cooling, having the form of thin quadrangular plates, sometimes square, oftener parallelograms, not over ¼ of an inch in diameter.‡

(*e.*) After being heated, the dry earth remaining, is about 32 per cent.; the crystals contain 1 proportion of earth, 52, and 12 of water, 108=160.

(*f.*) At 60°, soluble in 51½ parts of water; boiling water takes up half its weight.

---

* Dr. Crawford observed a difference between the muriate of strontia and that of baryta, in 1790. Klaproth confirmed the views of Dr. Hope.

† Vide Edin. Trans. IV, 44.

‡ In both cases, the decomposition of the sulphate is the cheapest process; see the articles sulphate of baryta and sulphate of strontia. The carbonate is managed with the greatest ease.

The composition of the hydrate of strontia according to Dalton, is 1 proportion of earth and 12 of water.

(*g.*) *Strontia imparts to the flame of boiling alcohol, a blood red color;* its effects on the test colors are the same as those of baryta, lime, &c.

(*h.*) No union with fixed alkalies or baryta.

(*i.*) Heat readily separates the water from the hydrate, and from the crystals.

(*j.*) *The compound blowpipe melts the earth itself,*[*] with the characteristic red flame.

(*k.*) *This blowpipe produces a similar flame from every combination of strontia,* even from the native minerals.

(L.) DISTINCTIVE CHARACTERS—cannot be confounded with any thing except baryta, but it is lighter than that earth, less caustic, and attracts acids less powerfully; the strontitic salts being decomposed by baryta, produce different combinations with acids, are less poisonous, and give a different colored flame.[*]

5. POLARITY.—Like that of baryta, electro-positive, and of course it is attracted to the negative pole in the galvanic series.

6. COMBINING WEIGHT, 52—composed of strontium one proportion, 44, and oxygen one, 8=52.

STRONTIUM.

1. *Obtained from native carbonate of strontia, by the same processes as those which afford barium;* discovered by Sir H. Davy, in 1808.

2. PROPERTIES.

(*a.*) *Similar to those of barium;* has less lustre; difficult to fuse; not volatile.

(*b.*) *Action of air and of water, converts it into strontia;* in water, it produces hydrogen gas.

(*c.*) *Proportions of the constituents of the protoxide.*

Strontium, -	84.54, or 1 equivalent,	44
Oxygen, - -	15.46, or 1 " -	8
	100.00	52

3. THE DEUTOXIDE OR PEROXIDE of strontium is obtained in precisely the same manner as that of barium. According to Thénard, (II, 314,) it is best obtained by the action of the oxygenized water, or deutoxide of hydrogen upon strontia water; the peroxide of strontium precipitates in brilliant pearly crystals. This oxide, by

---

[*] First effected by Dr. Hare, 1802—3. See Phil. Trans. of Philad. It is one of the most refractory of natural substances.

heat, even that of a lamp, gives up its excess of oxygen, and becomes protoxide. It acts like the nitrates upon burning coals, causing increased combustion. When it is moist, it gradually loses the oxygen, and rapidly in hot water. It appears to contain just twice as much oxygen as the protoxide or strontia.

4. **Combining weight.**—This is estimated at 44.

5. **Polarity.**—*Electro-positive;* resorts to the negative pole of the galvanic battery.

6. **Uses, &c.**—Strontia has the same uses in chemistry as baryta. It is a test for carbonic and sulphuric acids; as a natural production, it is more rare, especially its carbonate; its sulphate is found abundantly in Put-in-Bay, Lake Erie; at Detroit, Mackinaw, Lockport, &c.

The salts of strontia are not poisonous; the pure earth is acrimonious like the other alkaline bodies.

The natural and artificial compounds of baryta, are heavier *than* those of strontia, and there are various points of difference found in their combinations. The nitrate of strontia is used to give a blood red color to artificial fire works.*

Sec. IV.—Magnesia.

1. **Discovery.**—In the beginning of the eighteenth century, exposed for sale as a panacea at Rome, by a canon, who called it powder of Count Palma; but Dr. Black, in 1755, was the first person who distinguished it clearly from other substances.

2. **Preparation.**

(*a.*) *In the arts.*—From the muriate and sulphate of magnesia, found in sea and saline water; they are decomposed by alkalies, or usually by their carbonates; magnesia may be extracted by acids from magnesian stones, and the salts thus obtained can be decomposed as above.

(*b.*) *In Chemistry.*—Ignite the common carbonate of the shops, or dissolve the sulphate and decompose it by any alkali or alkaline carbonate, wash thoroughly, and ignite the precipitate.

3. **Properties.**

(*a.*) In light spongy masses, or in a friable powder, which forms with water a paste destitute of cohesion; the carbonate is commonly seen in cubical cakes.

(*b.*) *Sp. gr.* 2.3; *still the cakes float awhile on water*, till they are filled by absorption.

(*c.*) *Taste insipid*, or slightly earthy; lime mixed with it sometimes communicates to it a slight degree of acrimony.

(*d.*) Mild, harmless, and without corrosive action on the living or dead animal organs.

---

* Ure, 2d Ed. 743.

(*e.*) *Affects the most delicate test fluids; if mixed with them in substance*,[*] e.g. cabbage infusion, violet tincture, and that of turmeric; but it is not sufficiently soluble in water, to impart the same power to that fluid.

(*f.*) *Does not slack with water.*

(*g.*) Nearly insoluble in that fluid, which takes up about $\frac{1}{5142}$ at 60°, and at 212° $\frac{1}{36000}$.[†]

(*h.*) *Absorbs water*, so that 100 becomes, in weight, 118; heat drives the water off, and the magnesia contracts again. It forms a hydrate with water, but it unites with this fluid without any sensible heat, and it is easily driven off at ignition.

(*i.*) Precipitated from acids in the state of hydrate containing probably one third water.

(*j.*) This hydrate, dried by a very gentle heat, is transparent: it is supposed to contain 1 equivalent of magnesia 20, and 1 of water, 9=29.

(*k.*) Native hydrate, of Hoboken, New Jersey, contains about 30 per cent. of water.

(*l.*) Alkalies do not combine with magnesia; alkaline earths unite with it by heat.

(*m.*) *Of very difficult fusion;* first melted by Dr. Hare's blowpipe, in the laboratory of Yale College.[‡]

(*n.*) Those minerals in which it is a large ingredient, are very infusible; hence soapstone is used in furnaces.

(*o.*) With lime, in excess, it melts in furnaces; for the lime, although itself infusible, acts as a flux.

4. POLARITY.—Magnesia goes to the negative pole, and is therefore electro-positive.

5. COMBINING WEIGHT.—Theory estimates it at 20; of which 12 is assigned to magnesium and 8 to oxygen, being 1 proportion of each.

6. CHARACTERISTICS.—Its sulphate is very soluble, while those of lime, baryta and strontia, are very insoluble: its nitrate and muriate are very deliquescent,[§] and soluble in alcohol: the bi-carbonates of potassa and soda do not precipitate it, on account of the carbonic acid.[‖] Oxalate of ammonia, which readily precipitates lime, does not precipitate magnesia, if the solution is moderately diluted.—*Turner.*

7. USES.—Magnesia is a very useful article of the materia medica; it is used as an antacid and cathartic. It seems however to be nearly inoperative, unless there is acid in the stomach, or unless acid is taken after it: all the salts of magnesia are bitter and cathartic.

---

[*] Probably this effect is, in some cases, owing to the fact, that the alkali used in decomposing the magnesian salt has not been perfectly removed by washing.

[†] Fyfe, quoted by Henry.

[‡] Con. Acad. Trans. Am. Jour. Vol. II, p. 290.

[§] The nitrate of lime is deliquescent.

[‖] The same is true, in a good degree, of lime.

The carbonate is most commonly used, but the pure earth, sold under the name of calcined magnesia, is sometimes preferred, because no gas is extricated from it in the stomach. Magnesia sometimes forms large and dangerous accumulations in the bowels, of several pounds weight, particularly when its use has been long persevered in, and the earth has not been duly evacuated, by acids, forming with it saline combinations. It sometimes enters into the clays, and other materials which go to form porcelain, in the fabrication of which, on account of its infusibility, it serves a valuable purpose. It is one of the four earths which form a large part of the crust of this planet. Soapstone owes its peculiar properties to magnesia, particularly its infusibility: magnesian stones, such as soapstone and talc, are much employed, not only to resist fire, but because they are so easily wrought by tools into any desired form.* They are used in building.

MAGNESIUM.

1. *Obtained in the same way as the other metals of the earths.*

2. A white and brilliant solid; (a little mercury still remaining in combination with it.)

3. *Sinks rapidly in water,* although surrounded by bubbles of gas.

4. *Both in air and water reproduces magnesia;* in air gains weight, as the balance proves, both with respect to this and other earths.

5. POLARITY.—Magnesium goes to the negative pole, and is therefore electro-positive.

6. The combining weight is estimated by Dr. Thomson at 12, and this, with 1 proportion of oxygen, forms magnesia, which is the only known oxide of magnesium, whose equivalent is of course, 20. There can be no doubt that magnesia is a metallic oxide. Hitherto chemists have been unable to make it absorb more oxygen.

SEC. V.—SILICA.

1. NAME.—*Silex is the Latin for flint,* which is composed of this earth, nearly pure; limpid rock crystal is almost pure silica, and several other siliceous minerals, as chalcedony, carnelian, opal, agate, &c. consist principally of this earth. The purest white sand contains little else: in the form of quartz it constitutes mountain masses, and in that of sandstone vast strata.

---

* Savage nations are acquainted with these uses: many of their containing vessels, especially vessels for cookery, are made of these minerals. After the aborigines of this country became acquainted with the Europeans, they made bullet moulds of soapstone; they were ingeniously arranged in halves, with a regular mouth, and were tied together by withes; I have such a specimen. Soap stone is also used to diminish friction in machinery.—*Am. Jour.* Vol. XIV, p. 376.

2. PREPARATION.

(*a.*)*Flint or rock crystal, ignited, thrown into water, and pulverized, affords silica sufficiently pure for every common purpose.*

(*b.*) But the more correct process is, to *mix these powders with* 3 *or* 4 *parts of carbonate of potash or soda,*[*] *and to melt the mixture in a crucible,* giving a higher heat, for half an hour or an hour, towards the last, and stirring it to prevent overflowing.[†]

(*c.*) *Caustic potash or soda is, of course, more energetic in its action,* but is more expensive; there is however an advantage in using caustic alkali, as it does not intumesce; if a silver crucible is used, it should be thick, that there may be the less danger of melting it.

(*d.*) Dissolve the melted alkalino-siliceous mass in water, filter, and add diluted muriatic or sulphuric acid as long as precipitation continues; the acid must be added in excess.[‡]

(*e.*) *The solution was formerly called liquor silicum, liquor of flints;* the vitreous mass from which it is obtained is deliquescent, and if the solution formed from it is dilute, and the acid is added gradually, the alkali may be saturated without precipitating any of the silica, but by evaporation to dryness the silica is rendered insoluble; the salt formed by the alkali may be dissolved out, and the earth thus obtained pure after ignition.

(*f.*) If the proportions of alkali and earth are reversed, then the compound produced is glass; of which mention will be made again.

3. PROPERTIES.

(*a.*) *White, insipid, harsh.*

(*b.*) *No effect on test colors,* no causticity, or any alkaline property, except its union with a single acid, the fluoric.

(*c.*) *Water does not directly dissolve silica, nor is it absorbed by that earth,* but when it is newly precipitated, it retains 26 per cent. of water, at 70° Fahr.

(*d.*) *When dry it is insoluble in water,* but when just precipitated, it is dissolved by that fluid, in the proportion of about $\frac{1}{1000}$,[§] and and if taken in its nascent state,[‖] it is even largely dissolved, and a bulky gelatinous hydrate is obtained, by a gentle evaporation: it is decomposed at a common temperature, but entirely at ignition. Dr. Thomson,[*] has shown that there are several hydrates of silica.

---

[*] Dry pearl ashes will do.

[†] It is recommended to dissolve the alkali first, in as little water as may be, to mix it with the silica, evaporate to dryness, and then fuse it, which may be done in a silver crucible. From my own experience, I should however recommend caution in the use of silver vessels, as they melt at about the degree of heat which produces the combination between the silica and the fixed alkali.

[‡] Dr. Henry remarks, "the alkaline liquor must be added to the acid, and not the reverse; for, in the latter case, the precipitate will be glass and not silica."—*Vol. I. p.* 642, 10*th ed.*

[§] Found naturally dissolved, as in the Geysers in Iceland, in which the solution is aided by soda, contained in the water: in the similar hot fountains of the Azores, silica is found in solution, &c. there are natural hydrates, and the immense number of crystals of quartz, evince that silex has been in solution on a great scale.

[‖] Particularly when the sulphuret of silicium is dissolved in water, and the silica is regenerated by the oxygen of that fluid, while its hydrogen is evolved, combined with sulphur.

(*e.*) *Insoluble in acids, except the fluoric,* which attacks it with great energy.

(*f.*) *When newly precipitated, soluble to some extent, in several acids,* and readily forms triple salts. Dr. Marcet recommends to precipitate it with muriate of ammonia.

(*g.*) Specific gravity 2.66.

(*h.*) *Infusible in any furnace,* but readily melted by the compound blowpipe; this was done originally by Lavoisier, with oxygen gas directed upon burning charcoal; afterwards, and often, by Dr. Hare, and in the laboratory of Yale College:[†] it forms a perfect glass.

(*h.*) *Silica, minutely divided, is dissolved at a boiling heat, by caustic fixed alkali;* the alkali should be twice the weight of the silica; after evaporation, the white puffy mass forms a clear solution with warm water, as already mentioned under (*e.*)

(*i.*) *Silica is hard,* and when rubbed between two plates of glass wears them so as to spoil their polish.

4. POLARITY.—I believe it is not distinctly determined. Several chemists of eminence regard silica as being an acid rather than an earth. This opinion is founded upon the fact that it saturates the fixed alkalies, and that in its natural combinations, it saturates the other earths. It has therefore been called the silicic acid, and its compounds, silicates. This however, appears to be a forced arrangement. In every other particular, silica is quite foreign from the nature of acids, and as regards its combinations with earthy and alkaline bases, it is not uncommon for one oxide to unite with another; the alkalies dissolve many metallic oxides, and potassa and soda readily dissolve alumina, and should therefore, upon this principle be called acids. The student will, however, do well to remember that the silicates mentioned in modern books, and frequently in the analyses of minerals, are compounds of silica with bases. Whether we regard silica as an earth or an acid, there appears no reason why these combinations should not take place in definite proportions, such as are actually found to exist.

5. COMBINING WEIGHT.—According to Dr. Thomson, it is 16, of which one proportion is oxygen, 8, and one silicium, 8. According to Berzelius, it is 1 proportion of silicium, and 3 of oxygen.

---

[*] First Principles, Vol. I, p. 191.

[†] Not first by Dr. Clarke, as stated by Dr. Henry, Vol. I, p. 643, 10th London ed.

SILICIUM, OR SILICON.*

Remark.—The student may omit this head until he has studied the fluoric acid, and its compounds.

1. PROCESS.

(*a.*) Iron seven parts, silica five, and from $\frac{1}{4}$ to $\frac{4}{5}$ of soot, fused in a blast furnace, gave an alloy of silicium and iron.

(*b.*) Purified potassium, when heated in silicated fluoric acid gas, burns, condenses the gas, and gives a brown substance.

(*c.*) This boiled in water, and dried, burns in oxygen gas, and produces only silicated fluoric acid, and silica.

(*d.*) "The residue, treated with fluoric acid, gave silicated fluoric acid, and its color was rendered much darker."

(*e.*) "Thrown on a filter, washed and dried, it was pure silicium, which may be obtained also by heating potassium in a glass tube, with dry silicated fluate of potash."

(*f.*) "The product by being well washed with water, yields a compound of silicium and hydrogen, from which the latter may be detached by heating in a crucible."†

2. PROPERTIES.

(*a.*) *Color, deep nut brown,* without lustre, and acquires no brilliancy from a burnisher; no resemblance to a metal; resists friction like an earthy substance.

Incombustible, in common air, or even in oxygen gas.‡

---

[*] Sir H. Davy, (as already mentioned with respect to lime,) by driving the potassium through the earths heated intensely, succeeded so far in decomposing several of them, that the mass exhibited metallic points, and the potassium became potash. No considerable masses of metals were obtained in this way, but in general there was sufficient evidence that they were decomposed, and in this manner he was the first to ascertain that silica is a compound of oxygen and a base.

[†] Ann. de Ch. et de Phys. Vol. XXVII, 337.—Am. Jour. Vol. IX, p. 377.—Henry, Vol. I, p. 641, 10th Ed.

The best method of decomposing silica, is by taking it in the form of double fluate of silica and potash or soda; the latter is preferred, because it contains the greatest quantity of silica. To prepare it, the aqueous solution of silicated fluoric acid is mixed with the carbonate of soda, when the double salt, which is nearly insoluble, precipitates, and is washed and dried at a heat above 212°. This is stratified with thin slices of potassium, in a glass tube, hermetically sealed at one end, and the mass must be uniformly heated, and at once, by a spirit lamp. Even before ignition the silica is reduced with a hissing noise, and some appearance of heat, but if the matter is dry no heat is evolved.

The resulting brown mass, after being thoroughly freed from acid and saline matter, by water repeatedly applied, at first cold, and in abundance, and at last boiling hot, is then ignited, to expel hydrogen. It is then washed in diluted hydro-fluoric acid, to remove any siliceous particles, and is again washed and dried. For the details see Ure's Dict 2d Ed. p. 718, and Ann. of Phil. Vol. XXVI, p. 116.

[‡] When first obtained, and before it is freed from hydrogen, it burns when heated, even in the open air, but if carefully ignited first, in seclusion from the air, to expel the hydrogen, it becomes uninflammable.

(*b.*) *Not attacked by water, or sulphuric, nitric, or nitro-muriatic acid. Infusible, and unalterable by the blow pipe,* and apparently one of the most infusible of bodies.

(*c.*) *Fluoric acid, with a little nitric, attacks it vigorously.*

(*d.*) After ignition, chlorate of potash does not affect it at any temperature. Nitre acts upon it violently at a white heat. If a fragment of carbonate of soda be introduced into the mixture, it detonates.

(*e.*) Vapor of sulphur unites with the ignited silicium, and becomes incandescent.

(*f.*) The resulting sulphuret decomposes water rapidly, and evolves sulphuretted hydrogen; silica is generated, and the water dissolves it, and becomes gelatinous, but after it is dry, it remains a cracked mass, and is entirely insoluble in acids. It is observed that this solubility of silica just formed, may explain the existence of siliceous crystals in closed cavities, which could never have contained water enough for the solution of the materials, unless they were originally in a much more soluble state.

(*g.*) *Silicium burns in chlorine at a red heat,* and forms a yellow volatile liquid, smelling like cyanogen, and depositing silica on the addition of water.

(*h.*) *Detonates when heated with carbonate of potash, and with the hydrates of fixed alkalies, and of baryta,* producing at a temperature below redness, vivid incandescence; it acts upon the alkali of nitre, after the acid is destroyed by heat.

(*i.*) *A non-conductor of electricity.*

(*j.*) Alloys of silicium are obtained by heating silica along with other metals, but silicium once extricated from oxygen, does not form alloys.

(*k.*) *It stains, and sticks strongly,* even when dry, to the glass vessels in which it is kept.

(*l.*) *When silicium is heated in vapor of potassium it takes fire,* producing a compound of silicium and potassium.

Remarks.—It is not easy to class silicium. It can scarcely be called a metal, as it is infusible, is a non-conductor of electricity, and has none of the physical properties of a metal. It may be regarded as a combustible, since it burns in chlorine, and those who choose to consider its combination with sulphur and potassium, with emission of heat and light, as a combustion, will of course add those instances as proofs of its combustibility. On the whole, it is perhaps more allied to boron and carbon, than to the metals; but carbon has two metallic properties; it is a conductor of electricity, and in the form of plumbago, and of fused charcoal, it has the metallic lustre. Some of the metals, as uranium, titanium, and columbium, are rather remote in their properties from those usually assigned to metals.—*Berzelius.*

---

* See Ann. de Chem. et de Phys. Vol. XXVII, p. 337, and Ure's Dict. p. 719.

GLASS.[*]

1. HISTORY.—*Known to the ancients.*—Glass beads were found among the ornaments of mummies in the catacombs, near Memphis, supposed to be 1600 years older than the Christian era; glass was known to the Romans, and glass vessels were discovered in the houses of Herculaneum, and a coarse glass in the windows of the houses in Pompeii, which were destroyed by an eruption of Vesuvius, A. D. 79; glass lachrymatories are found in the tombs of the ancient Greeks.[†] Glass was however, with the ancients, merely an article of luxury and curiosity, and it is only in modern times that it has come into general use.

In Europe, it was first made at Venice, and its use, in windows of private houses, was introduced into England in the tenth century, nor was it common until the 13th or 14th century.

2. COMPOSITION.—*Essentially a compound of silica, and fixed alkali*, with however, various adventitious ingredients; sometimes glass is made of lime, or of the coarsest refuse ashes, and sand.

3. *Principal kinds.*—Flint glass; crown, or window glass; broad, or coarse window glass; plate glass; green bottle glass.

(*a.*) *Flint Glass.*[‡]—120 parts clean white sand, 40 purified pearl ashes, 35 litharge, or minium, 13 nitre, and a little oxide of manganese; or 100 white sand, 80 to 85 red oxide of lead, 35 to 40 of pearl ashes, 2 or 3 of nitre; or, (in England,) purified Lynn sand 100 parts, litharge, or red lead, 60, purified pearl ashes 30. To remove the color, derived from combustible matter, or oxide of iron, a little nitre, or black oxide of manganese, or arsenic is added; the oxigen contained in these substances, either burns the combustible matter, or brings the metallic oxides that may be present, to such a state that they do not color the glass. The fusion takes about thirty hours. The lead gives to this species of glass greater toughness and softness, so that it can be cut, ground, and highly polished, and greater density, and higher refractive power. It is the glass of our tables, of optical instruments, and lustres.

---

[*] Glass is an example of what is called a *vitrification.* Many earthy and saline substances, and metallic oxides, either alone, or mixed, become by fusion, dense, hard, brittle, shining bodies, usually breaking with a conchoidal fracture, and having more or less of transparency. The slag and scoriæ of furnaces are imperfect vitrifications.

[†] Specimens were brought out by Mr. Jones, author of "Naval Sketches," and are now in the Cabinet of Yale College; they are supposed to be 2200 years old. Some of them are beautifully irised; the glass is perfect, and is a little green in its shade of color.

[‡] Called flint glass, because it was formerly made from flints; and it has been called crystal glass, being sometimes made from rock crystals; both are ignited and thrown into water to crack them, and they are then pulverized.

(*b.*) *Crown Glass.*—200 parts of good soda, (or pearl ashes,) 300 pure sand, 33 lime, 250 to 300 ground fragments of glass; this last addition is not essential; or, by measure, fine sand purified 5, best kelp, ground, 11; by weight, sand 200, kelp 330. Professor Sweigger discovered that sulphate of soda might be used in the manufacture of glass, and his proportions are, sand 100, dry sulphate of soda 50, dry quick lime, in powder, 17 to 20, charcoal 4. The result is a good glass; the sulphate of soda, aided especially by the charcoal, is decomposed, and its soda combines with the silica and the lime aids in producing the vitrification. The materials of glass are combined, in part, by a preliminary operation, called *fritting*, performed in a furnace, by which sulphur and other volatile matters are expelled, previous to the full fusion, and the alkali is brought into combination with the silica, so that it is not volatilized by a higher heat.

(*c.*) *Broad glass.*—Soap maker's waste 2,* sand 1, kelp 1, mixed, dried and fritted; or, soap boiler's waste, 6 bushels, 3 of kelp, and 4 of sand; these form a pretty good broad glass. The materials are calcined for 20 or 30 hours before fusion, and then it requires 12 or 15 hours to melt them into perfect glass.

(*d.*) *Plate glass*—300 lbs. sand, 200 soda, 30 lime, 32 oz. manganese, 3 oz. azure, and 300 lbs. fragments of glass; or pure sand 43, dry soda 26.5, pure quick lime 4, nitre 1.5, broken plate glass 25=100, from which 90 parts of good plate glass may be obtained.

(*e.*) *Bottle glass.*—Common sand,† 100 parts, 30 of varec or coarse kelp, 160 leached ashes, 30 pure ashes, 80 of brick clay, about 100 broken glass; or, soap maker's waste and river sand, in proportions determined by practice. Common sand and lime, with some common clay, and sea salt, form a good mixture for bottle glass.

3. *Pastes are artificial imitations of the gems.*—They are very fine glass, rendered fusible by borax and other fluxes, and stained by oxides of metals. Rock crystal, or other very pure siliceous matter, is selected, pulverized very fine, and mixed with the other substances; the following examples will shew the composition.

Pulverized rock crystal, or flint, 8 oz. purified pearl ashes, 24 oz. these are fritted together, and then mixed with 12 oz. of white lead, and 1 oz. of borax—after fusion, 5 drachms of nitre are added; or, rock crystal pulverized, 3 oz., white lead, 8 oz., and borax, 2 oz., and half a grain of manganese. This is a paste in which the lead and borax answer the purpose of a flux.

---

* Consisting of refuse lime, that had been used to give causticity to the alkali, the insoluble part of the kelp or barilla, and some salt and water, all in a pasty state. —*Ure.*

† In England, the government will not permit any but coarse sand to be used in this manufacture, lest the common glass should be so good that the sale of the flint and other superior kinds of glass, which pay a higher duty, should be diminished.—*Parkes.*

Some principal colors are given by the following oxides of metals. Antimony gives yellow, and the same is produced by muriate of silver, and by oxide of zinc, white clay, and yellow oxide of iron; manganese produces violet; gold, many shades of violet, red and purple; cobalt, blue; chrome, green, or red; iron, red, and a great many other colors and shades; and many varieties are imparted by mixtures of different oxides. Fluxes for the colors are made of borax, pearl ashes, lead, &c. These imitations of the gems, except in lustre, are often equal in beauty to the originals, but they are soft, and easily defaced.

(*g.*) *Stained glass.*—The art of staining glass was introduced into England, in the 13th century, in the reign of king John. Many of the ancient Gothic churches in Europe, are ornamented by stained glass, the panes of the windows having pictures painted upon them. The glass used for this purpose, is made without oxide of lead, because that addition would make it too fusible, so that it would lose its shape during the second heating. The colors, ground in water, are laid on the glass, which is heated under a muffle, until the colors are melted, and united to the glass; and the pieces, to prevent their bending, are supported upon the biscuit of unglazed porcelain, or some other suitable substance.*

(*h.*) *Medallions encased in glass.*—They appear to be something like the biscuit of porcelain introduced into the glass, while in fusion; they are called *crystallo ceramie*, and are very beautiful.†

(*i.*) *Enamels are glasses, more or less opake*, stained with various colors; one of the most common is stained by oxide of tin or oxides of tin, arsenic and lead more or less mixed, as in watch faces.

Dr. Bigelow informs us,‡ that the beautiful imitation of porcelain, made in Boston, and now seen in the shops, is flint glass, containing a portion of white arsenic, upon which its opacity depends.

Remarks.—Green glass is much harder and less fusible than white flint, and as it contains no lead, it is also much fitter to contain corrosive chemical agents. Glass is very ductile, as is proved by its being spun into the most delicate threads; it is highly elastic, forming the finest toned bells and musical instruments; it expands and contracts less than any other substance by variation of temperature, and might therefore be used for clock pendulums; it is a bad conductor of heat, and a large mass of it poured in fusion into water, will remain red hot in the inside, for several hours after the outside is solid.

---

* I have seen modern stained glass in the windows in the University, Cambridge Eng. and in Hartford, Conn. (the latter of Boston manufacture,) less beautiful, however, than the ancient.

† Heads of Washington, Franklin, Napoleon, and other distinguished persons, have been executed in this way.

‡ Technology, 460.

3. MECHANICAL OPERATIONS.—It would exceed the limits of a work like this, to describe even the outlines, of the ingenious operations by which glass is fabricated into the various forms in which we see it. In general, it is blown by the breath of the artist, injected through an iron tube, to which the melted glass is made to adhere, by dipping and rolling one of its ends, repeatedly in the crucible; and in the early part of the operation, while it is inflated, it is rolled on a smooth iron plate. I will briefly describe a few cases, most of which I have seen, and they will serve as examples for the rest. A porter bottle is partly blown, and then allowed to drop into a mould of copper, brass, or iron, in which, by a vigorous inflation, it receives its form; the bottom is indented to make it stand; the mould opens with a hinge, and another workman attaches a rod, having a little melted glass upon it to the bottom of the bottle; the neck is cracked off by touching it with an instrument wet with cold water, and the broken mouth, being again heated, is shaped by introducing a revolving iron into it, and a coil of melted glass is wound around to give it strengh; it is then carried away to the annealing furnace, to be gradually cooled. Glasses consisting of several parts, are blown separately, opened, moulded, shaped and stuck together while hot; the foot of a wine glass is blown, as well as the conical part.

A glass tube is drawn, by blowing a little into a mass of melted glass on the end of the iron tube, and then an assistant pulls the mass with iron pincers, and moves off rapidly or slowly, as the tube is to be coarser or finer.

Plate glass is cast on an iron table;* an iron cylinder of five hundred pounds weight or more, is passed over it to spread it smoothly, and it is finished by being ground and polished. Plates have been made of twelve feet by six. The smaller glass plates are blown, opened by a chisel and mallet, and cut, while hot, by shears, spread open upon a table, and afterwards annealed and cut by the diamond. Plates can be made in this way, of four or five feet, by two or three. Window glass is blown, and either cut open and spread; or in the best kinds, after being blown into a huge globe, this is fixed at the bottom, to another iron tube, or rather an iron rod; the neck is cracked off, and the mouth is heated at a flaming furnace, while the bottle is made to revolve rapidly, and by the centrifugal force, the mouth opens and widens, and the globe suddenly expands into a wheel, forty eight or fifty inches in diameter, called by the workmen, a table; this operation is called *flashing*, and is very beautiful. The glass, after being annealed, is cut up into squares by a diamond; the centre piece by which the wheel was supported, is called the bull's eye, and is often seen in entry windows. Broad glass is blown into a conical form; cracked longitudinally while hot, by touching it with a cold wet iron, and it is then spread out on a table, whence its name; it is afterwards annealed and cut.

---

* Copper tables and rollers were formerly employed, but the copper is apt to crack.

The annealing of glass, which means the cooling of it, very slowly, in a peculiar kind of furnace, is important to prevent its cracking by slight movements, or jars, or variations of temperature.

Prince Rupert's drops are made by pouring melted green glass into water, when the portions assume a tadpole shape; they will bear the moderate blow of a hammer, if lying on a smooth table, but if the point is broken off, they explode into a thousand pieces. That this peculiarity depends on an unequal contraction produced by sudden cooling, is evident, because if the drops are gradually heated red hot, and gradually cooled, they will no longer fly on having the point broken.

The Bologna vial is blown with a thick bottom, but is cooled in the air, without being annealed; it will bear to be struck upon a table with some force, but if a fragment of glass or sand be dropped into it, it flies to pieces, and frequently it does so by slight changes of temperature; even, as I have observed, by the warmth of the hands. Cups of green glass, unannealed, have been made three inches thick at bottom, which were not broken by a musket ball falling from a considerable height, but were shivered, by a piece of flint of two grains weight falling into them.

SEC. VI.—ALUMINA.

1. NAME.—From alumen, the latin of alum, which has this earth for its basis; called also the argillaceous earth. Indicated by Geoffroy, in 1727, established by Margraff, of Berlin, 1756. Formerly called argil, because it was the basis of clays.

2. PREPARATION.

(*a.*) To a solution of alum,[*] in 20 parts of water, add liquid ammonia till precipitation ceases: or, precipitate by bicarbonate of potash; as a little sulphuric acid is apt to adhere, it may be re-dissolved in nitric acid, and the solution tried for sulphuric acid, by nitrate of barytes; when there is no farther milkiness, it may again be precipitated by the above reagents, or the nitrate may be decomposed by heat.[†]

(*b.*) Or, alum purified from iron, by repeated crystallizations, is dissolved in 4 or 5 parts of water, at 212°; add carbonate of potash in slight excess, to prevent the formation of sub-sulphate; digest a little while, filter and wash the precipitate with boiling water, to remove the acid entirely; but as some alkali may adhere to the earth, re-dissolve it in dilute muriatic acid, and decompose by ammonia, or its carbonate; wash the precipitate thoroughly, and give it a white heat, when it will be pure.

---

[*] Alum is apt to contain iron, which will remain when the salt is decomposed, and the earth dissolved by potassa; or, if dissolved, it will, after a few hours, precipitate in brown flocks.

[†] Ann. de Chim. XXXII, p. 64.

(*c.*) When alum is composed of sulphuric acid and alumina, with ammonia, and without any other alkali, the earth may be obtained by heat alone, which expels the ammonia, and decomposes the acid.

(*d.*) Galvanism discovers minute portions of the fixed alkalies and acids in the alumina prepared as above, but not when it is dissolved in muriatic acid, and precipitated by ammonia.*

3. PROPERTIES.

(*a.*) *Tasteless, inodorous, insoluble* in water; no effect on test fluids; infusible in furnaces. Sp. gr. 2. No alkaline property, except that of uniting with acids.

(*b.*) *Although insoluble in water, it attracts it powerfully;* when dry, it adheres to the tongue; when precipitated, and moderately dried, it is a hydrate, half of whose weight is water, which cannot be expelled except by a white heat.

After ignition, it attracts water so fast from the air, that balances show the increase of weight.†—*Henry.* Dr. Thomson states that there are two hydrates; the one composed of 1 equivalent of alumina, and 2 of water, forming a bi-hydrate; the other containing one equivalent of each.

(*c.*) *Easily diffusible in water, and forms with it a plastic mass;* and whether dry or moist, is impalpable between the fingers, or teeth, not being harsh and gritty, like silica; nor alkaline like lime, baryta, and strontia; nor rough, like magnesia.

(*d.*) If precipitated from a concentrated solution of an alkali, it is a light friable powder, and adhesive to the tongue.

(*e.*) If from a dilute solution, the dried precipitate is transparent, yellow, and brittle, compact, not earthy, and does not adhere to the tongue; this retains water forcibly, and has .15 of it, even after incandescence.

(*f.*) *Infusible in furnaces,* but fused by pure oxygen gas, on charcoal, and by the flame of the compound blowpipe, into an enamel, or a glass.

(*g.*) *Dissolved in the humid way by the fixed alkalies,* but very imperfectly by ammonia; the earth precipitated from alum, potash or soda, is re-dissolved by adding those alkalies in excess, and precipitated again by an acid.

---

* Phil. Trans. 1800, Davy.

† In Berzelius' hands, 15 1-2 per cent. were gained in a dry, and 33 in a humid air.

(*h.*) Alumina and baryta, in equal parts, boiled together in water, are dissolved.

(*i.*) Five parts of strontia being boiled on 1 of alumina, a portion is dissolved, and a compound of strontia and alumina is left undissolved; they unite also by fusion.

(*j.*) Alkaline solution of alumina, added to lime water, produces an insoluble precipitate of lime and alumina.

(*k.*) The same alkaline liquor boiled on lime dissolves no more than the water alone will dissolve; if alumina be mixed with the lime, much more lime is taken up than before.

(*l.*) Mixture of alumina and lime, the latter being in excess, melts under oxygen gas, directed upon burning charcoal, but in no proportions in a common furnace.

(*m.*) Alkaline solution of silica, with alkaline solution of alumina, on being mixed, gives a precipitate of silica and alumina, which fuses with an intense heat, into a milky glass or enamel.

(*n.*) Not soluble in alkaline carbonates.

(*o.*) Alumina unites by fusion with the fixed alkalies, and with most of the earths.—*Henry.*

(*p.*) This earth attracts coloring matter powerfully—see dyeing, under vegetables.

(*q.*) CONTRACTS PERMANENTLY IN THE FIRE; and becomes so hard as to give fire with steel. This is from an intimate union of the molecules, and especially when silica is present, as in the natural clays.

Wedgewood's pyrometer depends on this fact.—See heat, and the means of measuring heat.

4. POLARITY.—Electro positive; it is separated at the negative pole in the galvanic circuit.

5. COMBINING WEIGHT.—18 according to Dr. Thomson and Gay-Lussac, but chemists are not perfectly agreed as to this number.

6. DISTINCTIVE CHARACTERS.

(*a.*) Plastic with water, and imparts this property to large mixtures of other earths.

(*b.*) Precipitated as a hydrate, by alkaline carbonates, and by pure ammonia.

(*c.*) Precipitated by pure potassa and soda, and immediately redissolved by an excess of those alkalies; some choose to call this an acid property, but the alkali is not fully neutralized.

6. NATURAL HISTORY AND USES.

In various forms and combinations, it is one of the most abundant substances in nature. Clays are composed of alumina, for their characteristic ingredient, mixed with silica, oxide of iron and other substances. Those clays which, when burned, become red, contain oxide of iron, as is seen in our red bricks.

Alumina enters more or less into the composition of most soils, and it generally forms strata in valleys and low grounds and plains, where it arrests the water which has filtered down from the hills, and causes it to issue from the ground, in springs and rivulets. On account of its impermeability to water, clay is employed in the construction of tanner's vats, of artificial mill ponds, &c. where it is wished to retain the water.

In soils, this earth is of the first importance; perhaps it is not too much to say, that there cannot be a good soil without it. Its peculiar office appears to be, to retain moisture, and to prevent the waste of the soluble parts of animal and vegetable manures, which so rapidly filter through siliceous sand and gravel. Still, a soil may contain too much alumina; it will then be stiff, cold, and difficultly penetrated by the roots of plants; but if it is mixed with a good proportion of siliceous sand and gravel, it will be warm, still retentive of moisture, and sufficiently mellow.

Lime is an excellent ingredient in soils, as will be mentioned more particularly under the carbonate of that earth.

Alumina exists abundantly in rocks, especially in felspar, which is a constituent of granite and gneiss; in clayslate, steatite, asbestus, and serpentines, and in a great variety of minerals. It is nearly pure in the sapphire, and all the most precious oriental gems; it forms nearly the whole of corundum; it exists in a vast proportion of minerals, and forms a large part of the crust of the globe.

PORCELAIN AND POTTERY.

In all the manufactures which go under the general name of pottery, from the coarsest tile or water pot, to the most beautiful porcelain—in chemical lutes, in fuller's earth, and bricks, silica and alumina, in certain proportions, are the essential ingredients.

History.—Known from the remotest antiquity; the most barbarous nations fabricate rude vessels of baked earth, as well as by hollowing out soft stones; bricks were employed in the tower of Babel,* two thousand years before the Christian era, and they are found in the ancient Roman structures in Britain† and elsewhere. Earthen lachrymatories are discovered in the tombs of the ancient Greeks and

---

* In Yale College, are some Babylonish bricks brought out by the late Mr. E. Lewis, of N. Haven; they were never baked; they contain straw and bitumen, and some of them have "inscriptions in the arrow headed character;" the dimensions of the largest are twelve and three fourths inches square by three and a half thick.

† In the Roman wall at York, the bricks are seventeen inches long, eleven broad, and two and a half thick; and there is in Yale College, a piece of brick and mortar, from Roman baths at Paris, presented by Mr. Joel Root, who obtained it from the ruins.

Romans;[*] the celebrated Etruscan vases were found in the tombs of lower Italy.[†]

Water pipes were made by the ancients. I have one from Smyrna, sent out by the American missionaries, which indicates its antiquity by numerous layers of carbonate of lime, accumulated in the tube to the thickness of three or four inches, and evidently deposited from the water which ran through it.

The Egyptians ornamented the mummies in their catacombs, not only with glass, but with earthen figures, some of which were covered with a blue glazing made by the oxide of cobalt, the same material that is now used for this purpose. Porcelain was made by the Persian, and other eastern nations, before the Christian era, and the art is of high antiquity in China and Japan. It was introduced into Europe, early in the late century, and fabricated first in Saxony and France; it was established in England, about the middle of the late century, and the manufacture was brought to great perfection, by the late Mr. Wedgwood.[‡] The manufacture of porcelain has been within a few years, begun in the United States,[§] and beautiful porcelain is now made at Philadelphia, by Hulme and Tucker.

Materials of porcelain.—The Romish missionary, father D'Entrecolles, early in the 18th century, sent home some of the materials used by the Chinese, and called by them *petuntze* and *kaolin*, the former being undecomposed felspar, and of course fusible; the latter decomposed and infusible, in consequence of the loss of the alkali, which is one of its constituent principles.

The felspar is composed of silica about 60 or 70, alumina from 15 to 25, and from 10 to 12 per cent. of potash or soda.

Porcelain differs from stone ware in having a vitreous fracture and delicate translucence, which arises from its being composed of one fusible ingredient, while the infusible one preserves the vessels from losing their form in the fire.

Porcelain clays abound in this country, and the materials from Chester County, near Philadelphia, now used there, are of the first order in point of excellence. Such clays should be free from iron, or the ware will be colored.

Materials of pottery.—There is no difference in principle between the materials of pottery and those of porcelain, except that the latter and contain one fusible ingredient, and are purer. The pottery being opake, needs not the felspar, and it has a dull earthy fracture instead of a vitreous one.

---

[*] Specimens are in Yale College, brought out by Dr. Howe and Mr. Jones. Some of them are supposed to be of the age of Pericles, particularly those from the tombs near Athens. Dr. Howe informed me that he was present when they were taken from the tombs.

[†] I saw a collection of these in the British museum, sent out from Italy by the late Sir Wm. Hamilton.

[‡] The common pottery had been manufactured in England, time out of mind.

[§] I believe that Dr. Meade, of New York, was the first person who succeeded in this country in making true porcelain.

The most common earthen ware is made of pipe clay, often containing iron, which of course colors the ware when it is burned. A clay, much used in this country, is obtained from Amboy, N. Jersey, and is gray, both before and after it is burned.

The plastic property possessed by moist clay, and by means of which it is moulded, depends on the alumina; but the pieces would crack and be destroyed by shrinkage, were not the alumina corrected by the silica, which is not prone to shrink in the fire. If natural clays then have the requisite proportions of the two earths, and are free from iron, they have all the properties that are essential; and if a color is produced by burning, it does not prevent the clay from forming a useful ware, although it may not be beautiful. Magnesia frequently enters into the composition of clays, and is a valuable ingredient, as it is a very infusible earth, and contracts but little in the fire; but if there is much lime, it will act as a flux, and produce a distorted ware.

As the natural clays do not always contain a sufficient portion of siliceous earth, it is usual, in such cases, to mix with them siliceous sand or ground flints, the clay being first blended with water into a paste, and it is then uniformly mixed with the siliceous ingredient.*

Fabrication of porcelain and pottery.—There are important differences between the two, and there are many varieties of operations relating to both, but a few general facts may be stated. There is no analogy between these processes and those by which glass is made; they are in fact directly opposite; glass is "softened by heat, and wrought at a high temperature, whereas the clay is wrought while cold, and afterwards hardened by heat."—*Bigelow.*

There is much labor in preparing the materials, the detail of which would be foreign from the object of this work, in which only a few of the most important operations can be mentioned.

Circular conical vessels are moulded upon the potter's wheel, a very ancient instrument, mentioned by the earliest writers, sacred and profane. A mass of the prepared clay is placed in the centre, and it revolves by a movement given by the foot, or by some other power; the potter, his hands being moistened, to prevent adhesion, one hand being on the outside, and the other within, gives it a circular form, and he employs sometimes a rude instrument, like a knife, to aid in finishing the piece. Many articles, modeled in this way, being too thick, are afterwards turned in the lathe, to make them thinner.

---

* Pottery contains silica, two thirds, alumina, from one fifth to one third, and sometimes one five hundredth or one two thousandth of lime, and iron from the smallest portion to 15 or 20 per cent.—*Vauquelin, quoted by Parkes.*

Handles, spouts, and other appendages are made separately, and are stuck on afterwards, with a thin paste of the clay, called *slip*.

Vessels that are to have a peculiar form, oval, scalloped, fluted, &c. are made in moulds, usually of calcined plaster of Paris, which, by its absorbing power, aids in drying the articles, and the moisture is expelled from the moulds by heat, so that they are soon rendered serviceable again.

Burning or Baking.—The vessels, after they are dried, either in the air, or in stove rooms, are placed in earthen cases, called seggars, and these are so arranged that one covers another, in the oven or furnace, where they are gradually heated for about 12 hours, by flues, communicating from without, and the full heat is maintained from 24 to 48 hours; more or less, according to the size of the establishment, and the nature of the ware.* The furnace being gradually cooled, the pieces are withdrawn, and are then in the state of *biscuit*, as it is called: it will be a perfect pottery, only it is absorbent of fluids, and therefore cannot be used, except for promoting evaporation, when it is desired that the fluid should pass through the pores and be exhaled from the outside. It adheres to the tongue, because it absorbs its moisture.

Porcelain contracts so much in baking, that some tablets which I have from the Royal Manufactory at Sevres,† in France, which were marked off into ten equal parts, are shrunk one division, comparing them with those that have not been baked.

Magnesia very much diminishes the shrinkage of the porcelain, and, in the form of steatite, is now employed by the English manufacturers. Great quantities of bones are consumed in the English potteries; it is done for economy, for the quality of the ware is injured, as to firmness and weight, although it is white and translucent.

Ornamenting.—In the state of biscuit, the figures are usually put on; in the finer kinds, by the pencil, and in the most beautiful porcelain, by the best artists, with exquisite taste and skill; and often a separate figure or scene is painted upon every piece of an extensive set: the colors are metallic oxides. The ground oxide, in fine powder, is intimately mixed with gum water, acid of tar, oil of turpentine, or some other essential oil, and after the color is laid on, the fluid is entirely evaporated. The colors employed are the same as those mentioned under glass.

---

* Trial pieces are withdrawn, from time to time, to enable the manufacturer to judge of the state of the ware.

† This is a part of a very instructive collection, containing a complete suite of all the materials used in the manufacture of French porcelain, and in all their stages of preparation and fabrication, from the decomposed granite, up to the perfect vessel; embracing also a series of colors, applied upon the porcelain, and accompanied by explanatory and descriptive catalogues. It was presented to me by Mr. Alexander Brongniart, the superintendant of the manufactory, a gentleman well known for his valuable researches, and excellent works in mineralogy and geology.

Very beautiful designs are now fixed upon the common ware by aid of the copperplate printing press. The design, first painted, and then engraved upon copper, is printed with a metallic color, mixed with prepared linseed oil, upon *silver* paper, which, with the figure upon it, is immediately applied to the biscuit, and then rubbed with a hard roll of flannel, to make it adhere, and after about an hour, the article is immersed in water, which softens the paper, so that it is easily removed, and leaves the colored figure; the piece is next heated moderately in an oven, to dissipate the oil, and is then prepared to receive the glaze.

The porcelain is not always painted in the biscuit; sometimes it is painted on the glazing, and I believe this is generally done, on the most beautiful porcelain; it is then necessary to heat the vessels again, in the enameller's oven, that the coloring matter may be melted, and incorporated with the glazing.

Glazing.—To prevent the absorption of fluids, and to make the vessels more cleanly, they are covered with a vitreous coat, a thin glassy film, which, as long as it lasts, protects the ware below. In the case of the common stone ware, it is produced by throwing into the hot furnace, common salt, which is raised in vapor, by the heat, when the soda vitrifies the outside and forms a perfect covering, which is also safe and cheap.

The glazing, used on the common yellow ware, is composed of 40 pounds of ground flints, and 100 of litharge,* or of 100 of litharge, and 80 of Cornish granite.

For porcelain and the finer kinds of earthen ware, it is composed of white lead, ground flint glass, ground silex, and common salt.

The materials of the glaze are reduced to an impalpable powder, and suspended by agitation in water; the vessels are dipped in them, and they retain enough to form a perfect covering when they are again exposed to the heat of the furnace. This glazing is dangerous; on account of the poisonous nature of lead: lava and pumice stone, have been substituted in France with good success; and even ground flint glass, mixed with clay and water, has been found to answer; indeed, no protection would be better than the common materials of glass, was not the ratio of its contraction and expansion by heat, different from that of pottery, which would cause it to break. Metals and their oxides are sometimes mingled with the materials of the glaze, to give it color, in certain parts, as on the edges of plates, copper being used for green, and manganese for black.

Porcelain is occasionally covered with gold or platinum in substance. The gold is dissolved in nitro-muriatic acid, which is evaporated, leaving the metal in a state of minute division; it is next mixed with borax, and gum water, and by means of a volatile oil, applied to the article; it is then baked, and afterwards burnished. The lustre ware is made by applying an oxide of gold,[*] with a volatile oil, which is laid upon the vessels, colored by umber or red clay; this appears through the gold, and gives the copper tint. The steel colored ware is covered with the precipitate by muriate of ammonia, from the muriate of platinum, which is applied in a similar way, but upon a cream colored basis; and in both cases, it is introduced into the enameller's oven, where the heat dissipates the volatile principles, and the metals being left in their dull state, are afterwards burnished.

---

* The French use galena, the native sulphuret of lead, thence called potter's lead ore.

The ware is glazed before the gold and platinum are applied.

When prints are made to adhere to the biscuit, in the manner already described, as the glaze is applied afterwards, it is important that it should be transparent, that the colors may be seen through it.

It should be mentioned that the glazing on the best porcelain, particularly that of China, is composed entirely of feldspar, finely pulverized, and suspended in an aqueous fluid, which is said to be in China, a lye of fern ashes; no lead, or other metallic matter, enters into its composition, and it requires a very great heat to produce its fusion; it is much harder than the glaze on most European porcelain.

The Chinese ware is made so firm that it is merely dried before dipping it into the glaze, and does not require a previous baking to bring it to the state of biscuit.

In general, the European porcelain, although superior to the Oriental in whiteness and beauty, and in its exquisite ornaments, is inferior in hardness, infusibility, weight, capability of enduring sudden changes of temperature, and in the permanency of its glazing. Some of the Saxon porcelain is said to be equal to the Chinese.

Crucibles are made of the most infusible clays, and pipes and tiles are manufactured upon similar principles with those that have been explained.[†]

Bricks, of every variety, are merely rude pottery.

Fire Bricks are made of very refractory clay, called fire clay, and are both more infusible and worse conductors of heat than common bricks. They are sometimes prepared so as to be soft, or capable of being cut, in order that they may be adapted to different purposes, and the fire, as they are used, hardens them afterwards; at other times they are burned hard at first. Those manufactured at New

---

[*] A private letter to the author from Mr. Accum, in 1809, mentioned, that fulminating gold was applied in this way; if so, doubtless its explosive character was destroyed by the combustible matter of the oil of spike, with which it was said to be mixed.

[†] See Parkes' Essays, Vol. II; Gray's operative Chemist, and Bigelow's Technology.

Haven are made by using a fire clay, brought from Amboy, and found near the pipe clay; an equal measure of rather coarse siliceous sand is added, and they are baked in a potter's oven, with less heat than is employed for stone ware. Such bricks endure the intense heat raised in the cylindrical furnace stoves, in which the anthracite, and particularly the Lehigh coal is burned. On the side exposed to the fire, they become vitrified, and the impurities of the coal, consisting of earths, and oxide of iron, attach themselves to the bricks, in the form of a slag, and if the accumulated matter is not frequently detached, it eventually chokes the furnace.

The common bricks are burned in huge piles, called, in this country, *Kilns*, in England, *Clamps*. They are constructed of the moulded and sun-dried bricks, laid up with interstices, for the flame and hot air, and there are cavities left at the bottom, crossing the structure, in an arched form; in these the dried wood is laid, and the fire being kindled, is gradually increased, for the first twelve hours, after which it is kept at a uniform height for several days and nights, until the bricks are sufficiently hardened. Some are externally vitrified, or covered with a glaze, which is nothing but the melted materials of the bricks, and is not desirable, as good bricks can be made without vitrification. Some bricks are soft, and absorbent of water, and will split with the frost: others are firm, and will endure a great length of time. There is a great diversity in the clays of different places, as regards the goodness of the bricks made from them. Bricks, after being partially dried in the sun, are sometimes pressed in iron machines, which forces out water and air, and makes them more firm and handsome.

Terra cotta, or *Terre cuite*, (burnt earth,) is used by the moderns, as it was by the ancients, in making ornamental designs, " vases, imitations, and architectural decorations." The finer kinds of clay are employed, and they are with great facility moulded into any desired form.

Reamur's Porcelain.—This curious production might have been mentioned under glass, of which it is only an alteration, effected by the action of continued heat to the point of softening, and followed by slow cooling, when the glass loses its transparency, and undergoes a kind of crystallization. The change is most easily effected upon green bottle glass; it is found to be owing to the loss of the alkali by the heat, and that the glass thus changed will endure sudden changes of temperature, as well as the best porcelain. It is usually prepared by filling a common green glass bottle with white sand and gypsum; it is buried and pressed down in this mixture, in a covered and luted crucible, and baked in a potter's kiln, during the usual time of firing the ware, at the end of which period, it will be found changed into a kind of porcelain.—*Bigelow's Tech.*

ALUMINIUM.*

1. History.

(*a.*) *Discovered by Sir H. Davy,* who obtained, by galvanic power, a compound of iron and this metallic base, which effervesced in water, and produced alumina, and oxide of iron; also, by passing potassium, in vapor, through alumina heated to whiteness, the potassium was converted into potash, and metallic particles were obtained, which became white in the air, and effervesced in water; when the temperature was only at a red heat, an alloy of the two metals appeared to be obtained, which effervesced violently in water, and took fire spontaneously in the air.

2. New Process.

(*a.*) *Of late, Dr. Wöhler has obtained aluminium pure.*†—(The student may omit this process until he has studied chlorine.) Chloride of aluminium is formed by passing dry chlorine gas through an ignited porcelain tube, containing very dry alumina, intimately blended with charcoal, in consequence of its having been mixed in the state of hydrate, and then ignited in a covered crucible, with charcoal, sugar, and oil; the hydrate is made by adding an excess of carbonate of potash, to a hot solution of alum.

(*b.*) *Carbonic oxide gas was evolved,* and after the chlorine gas had passed for an hour and a half, the sublimed chloride of aluminium had collected in such quantity as to choke the tube.

(*c.*) *The chloride was in greenish yellow translucent scales, resembling talc,* deliquescing into a clear liquid, and combining with water, with heat, and even ebullition, if the quantity of water was small, and muriate of alumina was formed.

(*d.*) *Potassium decomposes the chloride of aluminium, and evolves the metal.*—The action is too violent for glass, which is destroyed by the heat disengaged. It succeeds in a platinum crucible, the cover being secured by wire, and the heat of a spirit lamp applied; but the crucible becomes red hot.‡

(*e.*) *The potassium should be free from carbon,* and the quantity not over the size of ten peas, and so proportioned, that none of the chloride may sublime, during the decomposition, nor the resulting mass be alkaline.

---

* Aluminum would seem preferable, but I adopt the orthography already introduced.

† The first hint was given by Prof. Oersted, in consequence of his having obtained what he believed to be aluminium, by acting upon chloride of alumina, by an amalgam of potassium.

‡ To prevent the possibility of deception, the experiment was repeated in a porcelain crucible, and with complete success.

(*f.*) The mass in the crucible is found to be melted, and of a dark gray color, and when put into water after it is cold, the saline matter is dissolved, an offensive hydrogen gas is evolved, and metallic scales remain, which after being thoroughly washed in cold water,* are pure aluminium.

3. PROPERTIES.

(*a.*) *A gray powder very similar to that of platinum*, in small metallic scales or spangles, or in slightly coherent spongy masses, having in some places a tin white lustre, rendered more distinct by pressure on steel, or in an agate mortar.

(*b.*) *In fine powder, a non-conductor of electricity*, but becomes a conductor after fusion.†

(*c.*) *Fusible at a higher heat than that which melts cast iron.*

(*d.*) *Ignited in the air, it burns vividly*, and the product is aluminous earth, white and considerably hard; sprinkled in powder, in the flame of a candle, it gives bright scintillations, like iron in oxygen gas.

(*e.*) *Ignited in pure oxygen gas, it burns with great heat and light*, and the resulting alumina is partially vitrified, yellowish, and hard as corundum; it even cuts glass. When burning in glass, it appeared to reduce the silicium, producing a semi-fused brown spot.

(*f.*) *Near ignition, it burns in chlorine gas*, and chloride of aluminium is formed.

(*g.*) *Not oxidized nor tarnished by cold water;* near ebullition, hydrogen gas is feebly evolved, and scarcely any oxidizement is observed.

(*h.*) *No action with strong sulphuric or nitric acid* in the cold, but with heat, the former is decomposed, and sulphurous acid gas evolved; it is dissolved in dilute muriatic and sulphuric acid, and hydrogen gas extricated.

(*i.*) *Dissolved readily and entirely in dilute solution of potash, and even in ammonia*, hydrogen gas being evolved, and much alumina held in solution.‡

4. COMBINING WEIGHT.—Not accurately ascertained; it has been already stated, that the number 10 has been adopted, and that it combines with one proportion of oxygen, 8, to form alumina, whose equivalent is of course, 18.

---

* The solution is neutral, and contains some alumina, formed, as it is said, in consequence of a combination between chloride of potassium, and chloride of aluminium.

† It is remarkable, as Dr. Wöhler observed, that metallic iron, *in fine powder*, is a non-conductor of electricity, so that this property of metals seems to depend on their form, or, possibly, on intervening air. Perhaps if silicium were melted, it might become a conductor, and thus be assimilated to the metals.

‡ Dr. Brewster's Journal, No. 17, p. 178.

5. Polarity.—*Electro-positive*, as appears from the original experiment of Sir H. Davy, in which it was attracted to an iron wire connected with the negative pole of the galvanic series.

Remark.—That alumina so extensively diffused and so familiarly known, should contain a metal, distinct and remarkable in its properties, and with the aid of potassium, so easily obtained, is a very interesting confirmation of the views of the illustrious Davy,* and must give celebrity to that of Dr. Wöhler.

Should the basis of the most important of the earths, namely, silicium, which Prof. Berzelius has, by the aid of the same agent, potassium, now placed fully within our reach, eventually prove, after fusion, to be truly metallic, it would be an interesting addition to the series; but in any event, the great fact that the earths are all oxides, is sufficiently established.

Sec. VII.—Zirconia.

1. Natural history and discovery.

Never found pure in nature; discovered first in 1789, by Klaproth, in the jargon or zircon, a precious stone from Ceylon, in which he found 37.5 silica, .5 nickel and iron, and 68. of the new earth, which from its parent mineral, he called zirconia. In 1795, found by him in the *hyacinths* of Ceylon, and in 1796, discovered by Morveau, in those from the brook of Expailly, in France; Vauquelin confirmed the discovery by farther experiments.†

2. Process.

(*a.*) To the pulverized zircon, add three or four times its weight,‡ of caustic potash, and fuse it in a silver crucible, throwing in the mixture, spoonful by spoonful, and waiting for the fusion of each portion before another is added, and after all are fused, increase the heat and maintain it for an hour and a half. Wash the contents of the crucible abundantly in boiling hot water, to remove the alkali. Now add muriatic acid to dissolve the zirconia, some silica is taken up by the acid, which is precipitated by heating the fluid, and removed by filtration. Lastly, add potassa; the zirconia precipitates; or it may be thrown down by carbonate of soda, and must then be washed sufficiently with pure water.

---

* Whose premature death, the friends of science and mankind will long deplore.

† Dr. Thomson, of Glasgow, has discovered 18 per cent. of zirconia, in the Sillimanite, a new prismatic mineral species found at Chester, in Saybrook, Conn. and first analyzed, named, and described by the late Prof. Bowen, who found it to consist of alumina, 54.11, silica, 42.66, iron, 1,99, and water .51. Dr. Thomson found a similar constitution, except that he discovered the zirconia as above stated.—*Am. Jour. Vol. VIII*, 195. 217; *Vol. XII*, 159, *and Vol. XVI*, 207.

‡ Five or six times, Four. II, 210—nine times, Ure's Dict. 815.

(*b*.) Or, to 1 part powdered zirconia, add 2 of potassa, and heat it for one hour in a silver crucible; add distilled water, filter and wash well the insoluble part, which will be a compound of zirconia, silica, potash and oxide of iron. Dissolve in muriatic acid, and evaporate to dryness, to separate the silica. Redissolve the muriates of zirconia and iron in water, and having washed the remaining silica with weak muriatic acid, to remove any adhering zirconia, add it to the fluid. Filter and precipitate the zirconia and iron by pure ammonia; wash the precipitates well, and then boil them in oxalic acid; this dissolves the iron and leaves the zirconia an insoluble oxalate, which is to be washed until no more iron can be detected in the washings.

The oxalate of the earth, which, when dry, is of an opaline color,* is then to be decomposed by heat in a platinum crucible.†

3. PROPERTIES.

(*a*.) A fine white powder, tasteless and inodorous, resembles alumina, but somewhat harsh to the touch; sp. gr. after being heated violently on charcoal, 4.3.

(*b*.) Infusible before the common blowpipe, but heated in a charcoal crucible protected by an earthen one, in a good forge fire, for some hours, becoming a substance like porcelain, insoluble in acids, suffering a partial fusion, and acquiring a gray color. In this state, it will scratch glass—gives fire with steel, and has the specific gravity of 4.3.

(*c*.) Perfectly fusible before the compound blowpipe of Dr. Hare, producing a white enamel.‡

(*d*.) *Insoluble in water, but is absorbent of it*, and when dried slowly after being precipitated form a solution, it has a yellow color; retains about one third of its weight of water; has a small degree of transparency, and resembles gum arabic. When heated red in a crucible of silver, it loses .37 of its weight.

(*e*.) No action on combustibles, or oxygen, or nitrogen.

(*f*.) Insoluble in alkalies, but *dissolved in alkaline carbonates.*

(*g*.) *Insoluble in acids, until it has been acted upon again by caustic potash*, and washed till the alkali is removed; it is next dissolved in muriatic acid, precipitated by ammonia and the washed hydrate,§ is then easily soluble in acids, forming salts, and those with the sulphuric, carbonic, and phosphoric acids, are insoluble in water. In general, the salts of zirconia are insoluble, and those that are soluble, have a sweetish astringent taste.

---

* For a third process, see Thénard, Vol. II, p. 295, and Ann. de Chim. et de Phys. T. XIII, p. 245.

† Ann. de Chim. et de Phys. T. XIV, p. 110.

‡ Am. Jour. Vol. II, p. 292.

§ The hydrate heated by a spirit lamp in a glass capsule, becomes red hot, as if it were on fire.—*Thénard.*

(*h.*) Zirconia differs from silica, in being much more soluble in acids, and in being insoluble in alkalies, but it is soluble in alkaline carbonates; in this last property it differs from alumina and glucina.

(*i.*) *There is a great resemblance between oxide of titanium and zirconia*, in most of their properties; but tincture of galls precipitates oxide of titanium reddish brown—zirconia in yellow flocks.*

4. Polarity.—From analogy, supposed to be *electro-positive;* and to be attracted to the negative pole of the galvanic series.

5. Combining weight, 48, consisting of zirconium, 1 proportion, 40, and oxygen, 1 proportion, 8.—*Thomson.* It has been supposed from some experiments of Berzelius, that it is 30 or 33.

ZIRCONIUM.

1. History and process.

Sir H. Davy discovered, that *when zirconia is ignited with potassium, the latter is oxidized*, and dark metallic particles are diffused through the alkali.

Berzelius has more recently procured this base, as he did silicium; that is, by heating with a spirit lamp, in a tube of glass or iron, a mixture of potassium and hydro-fluate of zirconia and potassa, carefully dried; at a temperature below ignition, the earth is reduced to the metallic state, and without any luminous appearance; the mass is next washed with boiling water, and then digested for some time in pure muriatic acid; the residue is pure zirconium.†

2. Properties.

(*a.*) *Black as charcoal;* it is a powder.

(*b.*) *Not oxidized by boiling water*, or sulphuric or muriatic acid, but dissolved by aqua regia, and hydro-fluoric acid, the latter evolving hydrogen.

(*c.*) *Zirconia burns intensely in the open air*, with a slight increase of heat, but far below luminousness, and produces zirconia.

(*d.*) It combines with sulphur, forming a chesnut brown sulphuret, insoluble in muriatic acid, and alkalies; but which burns brilliantly, regenerating the earth, and evolving sulphurous acid.‡

(*e.*) *Does not conduct electricity;* it is capable of being pressed out into scales of a dark gray color, having somewhat of the metallic appearance, but it is not perfectly settled whether it ought to be called a metal.

3. Combining weight—not accurately determined. See zirconia, 5.

---

* Ann. of Philos. XIII, 83.

† Turner, and Eng. Quar. Jour. XVIII, 157.

‡ Ann. of Philos. N. S. VIII, 123.

SEC. VIII.—GLUCINA.

1. NAME—NATURAL HISTORY—DISCOVERY.

From γλύκυς, sweet, because its salts have that taste. Discovered in the beryl and emerald, in 1798, by Vauquelin, who at the request of Haüy, analyzed the beryl to discover whether its chemical ingredients were the same with those of the emerald, as from physical considerations, he had conjectured that they were. The analysis proved the suspicions of Haüy to be well founded.

2. PROCESS.—(Th. I, 530.) Fuse pulverized emerald or beryl 1 part, with potassa 3 parts; dilute the mass with water, dissolve in muriatic acid, and evaporate to dryness, stirring the matter towards the end. Mix it with much water, and filter to separate the silica, which is more than half. The muriates of glucina and alumina are in solution; precipitate them by carbonate of potash,* wash the precipitate, and dissolve it in sulphuric acid. Add to the solution sulphate of potash; evaporate and obtain crystals of alum. When no more are formed by adding sulphate of potash, add carbonate of ammonia in excess, shake the mixture, and let it stand till the glucina is dissolved by the carbonate of ammonia, and nothing but alumina is left, then filter, and evaporate to dryness, when a white powder is obtained, which, after slight ignition in a crucible, is glucina, in the proportion of 16 per cent. of the stone. Euclase also contains 21.78 of this earth; and by Mr. Seybert's analysis, the chrysoberyl of both Haddam and Brazil, has as much as the emerald,† that is 15.80 glucina for the chrysoberyl of Haddam, and 16, for that of Brazil; the other constituents were for the latter, alumina 68.66, silica 5.99, oxide of titanium 2.66, oxide of iron 4.73, and water; for that of Haddam, 73.66 alumina, 4 silica, 1 oxide of titanium, 3.38 oxide of iron, and a little moisture. The existence of glucina in chrysoberyl had been overlooked by the first analysts, until it was discovered by Mr. Seybert.

3. PROPERTIES.

(*a.*) *Inodorous, tasteless, and insoluble in water;* but forms with it a paste of some tenacity. It is a fine white powder, resembling alumina, and like that adheres to the tongue.

(*b.*) *Does not contract in the fire*, nor affect the test colors.

(*c.*) Specific gravity 3.

(*d.*) *Infusible by the common blow pipe*, but perfectly fusible by that of Dr. Hare.

---

* The latter part of this process may be conducted differently from the description in the text. After precipitating the alumina and glucina, dissolve them in water acidulated by muriatic acid, and precipitate again by pure ammonia; then dissolve this in carbonate of ammonia, and proceed to the end as already directed. Or, starting from the same point: add to the precipitated earths pure potassa, which will dissolve the alumina, and a portion of the glucina, but that which remains, is this earth sometimes slightly colored by iron. For the mode of extracting glucina from the chrysoberyl, see Am. Jour. Vol. VIII, p. 105.

† Am. Jour. Vol. VIII, p. 105.

(*e.*) *Combines with potassa and soda, but not with ammonia,* although it is soluble in the carbonate of that, and of other alkalies, and in the caustic fixed alkalies.

(*f.*) *With all the acids forms salts,* with a sweetish astringent taste; they are decomposed by the alkalies, even by ammonia, which does not precipitate alumina, which glucina considerably resembles.

(*g.*) Resembles alumina in attracting coloring matter.

(*h.*) It is not precipitated by prussiate of potash.

(*i.*) *It absorbs carbonic acid, at the ordinary temperature of the air.*

4. COMBINING WEIGHT.—Stated by Dr. Thomson, and by Berzelius as 26.

5. POLARITY.—From analogy supposed to be electro positive.

GLUCINIUM.

1. This base has not been distinctly obtained, but the analogy which would lead us to admit its existence, is strongly supported by the following fact.

2. Sir H. Davy ascertained that by igniting potassium with glucina, the metal is converted into potassa, thus proving the existence of oxygen in the earth; dark colored particles, with a metallic aspect also appeared in the mass, and regained the earthy character by being heated in the air, and by the action of water, hydrogen gas being, in the latter case, evolved.

3. COMBINING WEIGHT.—Dr. Thomson concludes that the number for the earth must be 26, and if it consists of 1 proportion of metallic base, and 1 of oxygen, the latter being 8, the former will of course be 18.*

4. POLARITY.—Supposed from analogy to be electro positive.

SEC. IX.—YTTRIA.

1. NAME—NAT. HISTORY—DISCOVERY.

Name, from Ytterby, a quarry in Sweden, where the mineral was found, from which Yttria was first extracted.

Discovered by Prof. Gadolin, in 1794, during his analysis of this mineral, called after him, the Gadolinite, and confirmed by several eminent chemists since.

Yttria has been found, not only in the mineral mentioned above,† which yielded it in the proportion of 35 to 45 per cent., but also in another mineral, consisting of the metal tantalum, and yttria, called yttrotantalite, containing about 20 per cent., and in the yttrocerite, which has about 8 or 9 per cent. These minerals, as well as Gadolinite are found only in the quarry of Ytterby.

2. PROCESS.

---

* Thomson's First Principles, Vol. I, p. 318.

† Combined with black oxide of iron and silica.

(*a.*) *Let the Gadolinite be repeatedly digested in muriatic acid, and silica remains. To the fluid, add liquid ammonia, boil the precipitate in solution of potash, and filter. Dissolve the insoluble residue of the last process in diluted sulphuric acid, evaporate to dryness, ignite, and redissolve it in water; a precipitate falls down, which must be separated by the filter.

The filtered solution, when mingled with liquid ammonia, yields a precipitate which is Yttria.†

(*b.*) Fuse the Gadolinite 1 part, with caustic potash 2, wash the mass with boiling water, and filter the liquor, which will be of a fine green; evaporate till the oxide of manganese, in the form of a black powder, ceases to fall; then saturate the liquid with nitric acid. Digest the undissolved sediment in dilute nitric acid, which will dissolve the earth with much heat, leaving the silica undissolved, and the iron highly oxidized. Mix the two liquors, evaporate to dryness and redissolve and filter, which will separate any silica or oxide of iron that may have been left. A little carbonate of potash will separate any lime, and hydro-sulphuret of potash will precipitate any manganese; but if too much be added, it will throw down the yttria too. Lastly, ammonia will precipitate the yttria, which must be well washed and dried.‡

3. Properties.

(*a.*) *A fine white powder, infusible alone,* but with borax melts into a glass.

(*b.*) *Tasteless, smooth, and inodorus*—no effect on vegetable colors.

(*c.*) Sp. gr. 4.842, *greater than that of any earth.*

(*d.*) Insoluble in water, but absorbs it, and loses .31 of its weight when heated to redness.

(*e.*) *Soluble in alkaline carbonates,* but not in pure alkalies, like alumina and glucina; requires to dissolve it 5 or 6 times as much carbonate of ammonia as glucina does.

(*f.*) With acids forms sweet tasted salts, with some degree of austerity, and several of them are said to be colored, a fact not observed in any other metallic salts, but there can be little doubt that the color is owing to the adhering iron and manganese.

(*g.*) Solution of Yttria in muriatic acid, evolves chlorine after being long heated.

(*h.*) Oxalic [acid, and oxalate of ammonia, precipitate yttria like muriate of silver.

4. Polarity.—Supposed from analogy to be electro positive.

5. Combining weight, 42.

---

* Accum. Mineral, p. 137.

† For the process of Vauquelin, see Ann. de Chim. p. 150, XXXVI, and Henry, 10th Ed. Vol. I, p. 625.

‡ Ure's Dict.

YTTRIUM.

1. Not yet obtained isolated.

2. Yttria converts potassium into potassa, when aided by heat, thus proving the existence of oxygen in the earth, which also exhibits appearances of metallization, so that there can scarcely be a doubt that this earth consists of oxygen and inflammable or metallic matter.

3. Combining weight.—Dr. Thomson assigns 42 as the representative number of yttria, and supposing that the earth is composed of 1 proportion of oxygen, and 1 of metal, he states the latter at 34, for $34+8=42$.

* * * * * * *

Since the account of the earths was in type,[*] Prof. Griscom has been so kind as to forward to me the following notice of a new *earth*, which, as it is so named by its discoverer, I insert here rather than under the metals. The learner will observe that it is a different thing from the substance formerly called Thorina.—*See note, p.* 261.

Discovery of a new earth, named Thorina, and its metallic base, named Thorium.—M. Dulong communicated to the Academy of Sciences at Paris, on the 26th of July last, in a letter from M. Berzelius, the discovery of a new earth. "I have just discovered," says the Swedish Savant, "a new earth, which possesses almost all the properties of that which bore the name of Thorina, and which has been ascertained to be only a phosphate of Yttria. It is in consequence of this striking analogy, that I have retained the name of Thorina, for this new substance. This earth is white, and irreducible by charcoal and potassium. After being strongly calcined, it is attacked by none of the acids, except concentrated sulphuric, even after being treated with caustic alkalies. The sulphate of Thorina is very soluble in cold water, and almost insoluble in boiling water, so that it may be freed from many other salts, by washing the mixture with boiling water. Thorina dissolves easily in carbonate of ammonia. An elevation of temperature occasions a precipitation of a part of the earth; but on cooling, the precipitate disappears. All the salts of Thorina have a very pure astringent taste, very similar to that of tannin. The chloride of Thorium, treated with potassium, is decomposed with a triple deflagration. There results a gray metallic powder, which does not decompose water, but which, raised above a red heat, burns with a splendor almost equal to that of phosphorus in oxygen gas. Nevertheless, Thorium is feebly attacked by nitric and sulphuric acids. The hydrochloric, on the contrary, dissolves it with a brisk effervescence. Thorina, or the oxide of Thorium, contains 11.8 oxygen. Its specific gravity is 9.4. Thorina exists in a new mineral which has been found in very small quantities at Brevig, in Norway.—*Bib. Univ. Juillet*, 1829.

---

[*] But before it was struck off.

SIMPLE INFLAMMABLE AND ACIDIFIABLE BODIES, (not metallic,) AND THEIR COMBINATIONS WITH THE PRECEDING BODIES.

HYDROGEN—SULPHUR—CARBON—PHOSPHORUS—NITROGEN—BORON—UNKNOWN BASE OF FLUORIC ACID—SELENIUM.

Sec. I.—Hydrogen.

(*a.*) This inflammable body has been already described under the head of water, and is here mentioned again only for the sake of classing it.

(*b.*) With oxygen, it forms no acid, but it forms one with chlorine, as will be shewn in its place.

Sec. II.—Sulphur.

1. History.—Known from the remotest antiquity.

2. Sources.

(*a.*) *Volcanos, active, dormant or extinct;* sublimed by the subterranean heat, collects in craters and solfaterras, as near Naples, in Gaudaloupe, &c.

(*b.*) *Combined with metals,* forming numerous species of native sulphurets, as of iron, copper, lead, silver, &c. sublimed from them by artificial heat, but is not in this manner obtained pure; it is contaminated with the metals, with which it was combined.

(*c.*) *In sulphureous mineral waters*—imparting a disgusting odor, and the property of blackening white metals and their solutions; being suspended by hydrogen, it is deposited as that gas is exhaled, and is found in the channels, through which the waters pass.*

(*d.*) *In animals and plants*—found more or less in all animal bodies, as is proved by the production of sulphuretted hydrogen, during their decomposition. Among plants, in the rumices or docks, in the cruciform plants, as scurvy grass and cresses.

Sulphur was sublimed by Deyeux, from roots of horse radish and of dock.‡

(*e.*) *In rocks and stones,* along with gypsum and sulphate of strontia, and even with the primitive rocks in veins, and sometimes in indurated marl and compact limestone; arising perhaps from the decomposition of sulphurets.

---

* At Niagara, it oozes from the bank near the north side of the great Horse Shoe fall.—*Own observations, Oct.* 1827.

‡ Exists in eggs, in privies, in pits in which flax has been steeped, &c.

(*f.*) *In sulphuric acid*, forming a constituent of the natural sulphates of lime, baryta, strontia, soda, &c. and in the free sulphuric and sulphurous acids.

3. PROPERTIES.

(*a.*) *Sp. gr.* 1.99.

(*b.*) *Electric by friction;* color lemon yellow, but precipitated sulphur is at first white, and it becomes white if water be dropped on it while in fusion, and also if sublimed with watery vapor; the whiteness is supposed to be owing to a combination with water;* electricity, negative or resinous; a non-conductor of heat. Hence, a roll of it, grasped in the hand, crackles in consequence of its brittleness, and of its unequal expansion by heat.

(*c.*) *Emits a peculiar odor when rubbed or heated.*—Brittle and fracture brilliant; it has a considerable refractive power.

(*d.*) *Evaporates at* 170°, with a disagreeable smell; fuses at 185° or 190°; fluid at 220°, most perfectly fluid between 230° and 280°; when it is of an amber color.

(*e.*) It begins to thicken at 320°; at 350°, stiffens and acquires a deeper color;† is very tenacious between 428° and 482°, but from that to its boiling point, it grows fluid again, and on cooling, also, it recovers its fluidity; this may be repeated by sudden transitions of temperature in close glass vessels; otherwise the sulphur is volatilized.‡

Evaporates at 290°; it can be distilled from a glass retort into a receiver.

(*f.*) *Sublimes at* 600°.—The sulphur being thrown on an ignited iron, and covered suddenly with a bell glass, the latter is instantly lined with the sublimate called flowers of sulphur; melted, skimmed, decanted, and cast in moulds, this forms the best roll sulphur.§

---

* It is said also to acquire a paler color from adulteration with rosin, flour, &c.

† In this state, or when heated to 428°, it is poured into hot water, and is used to copy medals, they being impressed upon it while it is warm.

‡ Thénard, I, 107, quoted by Henry, Vol. 1, p. 380.

§ Rough sulphur is purified by melting it in cast iron bodies or retorts, covered with earthen ware heads; about six cwt. at once, and the distilled sulphur is drawn off into water, at the lower of three holes in the receiver; one being for the admission of the retort, and one for the escape of the vapors; the refined sulphur is cast in moulds made of beech wood. In subliming sulphur, the furnace is below, and the sulphur, melted in iron pots, rises into a room placed above, where it is condensed in flowers or sublimate.

It is sublimed also from thick iron pots, of the capacity of 10 or 12 cwt. by a lateral communication from its dome into a chamber, which, if intended for roll sulphur, may be not more than one fifth the size that would be requisite, if flowers of sulphur were to be made.—*Gray's Op. Chem.*

If the distillation is rapid and incessant, it will condense in the liquid form, and will be made into roll sulphur; if slow and with suspension at night, it will be in the form of flowers. Formerly, crude sulphur was merely melted, and when the impurities had subsided, it was ladled out and cast in moulds; the sulphur thus obtained was impure, and much was lost in the sediment; the best roll sulphur, as well as flowers, has been distilled or sublimed.

(*g.*) *In the arts, to form the flowers, it is sublimed in rooms lined with sheet lead.*

(*h.*) *Examined by the test fluids, to ascertain whether it is acid;* agitate it with infusion of cabbage or litmus.

(*i.*) *Crystallization*—natural in volcanos—often beautiful modified octahedra; *by art*—sulphur melted in a broad deep vessel, several pounds at once, (a crucible or earthen pot will answer,) when its surface congeals, break it and pour out the liquid interior.

(*j.*) *The cavity will be found lined with prismatic or needle form crystals,* of which the basis is an oblique rhombic prism.

(*k.*) *With water*—no action; if the sulphur be pure, it comes off tasteless; but precipitated sulphur is a hydrate, and is white; it was formerly called *lac sulphuris.*

(*l.*) *With liquid alcohol—no action;* in vapor they unite, a vial of alcohol being suspended in an alembic in which sulphur is sublimed, the spirit rises too, and a union results; water precipitates the sulphur.

(*m.*) Boiling essential oil of turpentine dissolves sulphur entirely, but not the usual impurities; hence, used to detect its adulterations; when properly purified, it has a fine sparkling brilliant yellow color.*

4. *An element in relation to our knowledge.*

(*a.*) *Sir H. Davy evolved sulphuretted hydrogen from it, by galvanism*—but is not certain that the gas did not come from decomposed water, lodged in the interstices.†

(*b.*) *Potassium evolves sulphuretted hydrogen,* with intense heat and light.

7. USES.

(*a.*) *An important article in the materia medica,* both internally, as a laxative, and externally, as a remedy against cutaneous diseases.

(*b.*) The basis of the manufacture of sulphuric acid.

(*c.*) Used with iron filings as a cement, and for matches.

(*d.*) In its viscid form for copying medals, &c.

(*e.*) The chief use is in the fabrication of gunpowder, of which it usually forms 15 per cent. For these and other purposes it is largely imported into this country from Italy, whose volcanic regions abound with sulphur, particularly in the Solfaterra near Naples, and it comes, in perhaps, larger quantities from Sicily than from Naples.

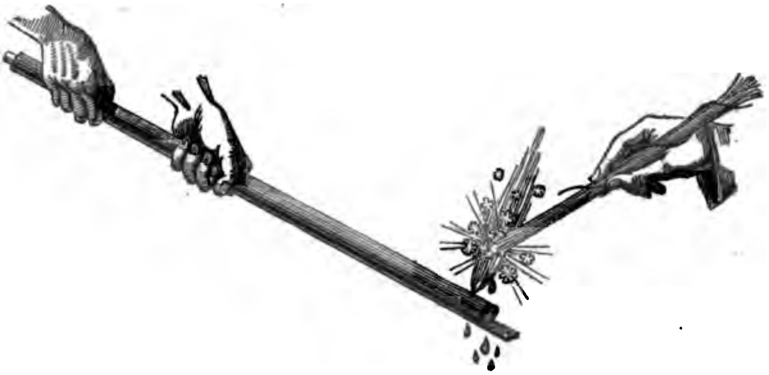
---

* Aikin's Dict. Vol. II, p. 353.

† Berzelius found that when metals combine with sulphur, as dry as possible, little or no sulphuretted hydrogen is exhaled.

(*h.*) To divide a bar of iron; when at ignition, or better at a white heat, if rubbed with a roll of sulphur, the iron melts and falls in drops of liquid sulphuret.

"If a gun barrel be heated red hot at the but-end, and a piece of sulphur be thrown into it, on closing the muzzle with a cork, or blowing into it, a jet of ignited sulphurous vapor will proceed from the touch hole. Exposed to this, a bunch of iron wire will burn as if ignited in oxygen gas, and will fall down in the form of fused globules, in the state of proto-sulphuret. Hydrate of potash, exposed to the jet, fuses into a sulphuret of a fine red color."—*Dr. Hare.*



5. **Polarity**—*Electro positive;* it goes to the negative pole in the galvanic circuit.

6. **Combining weight**, 16, hydrogen being 1.

8. **Pharmacy.**—No peculiar preparation is necessary to fit the best roll and flowers of sulphur for medical use. Whether it is acid may be learned from its taste, and from its effects on the test colors; if it turns the blue vegetable color red, it must be washed abundantly with hot water, and the addition of a little alkali will aid in removing the acid.

ACIDS.

Preliminary Remarks.

One of these bodies, vinegar, seems to have been always known to mankind. In the progress of time; accident, art and science have either developed or formed many more. There can be no doubt, that the acids are all compound bodies, and that the only one which remains undecomposed, the fluoric, has an inflammable base, like the rest; for, with this exception, all of the hundred or more that are known to chemistry, have inflammable or metallic matter, as their basis, and with only a few exceptions, it has been proved to be combined with oxygen, which, instead of being regarded as the exclusive acidifying principle, may still be viewed as sustaining this agency in nearly all cases.

Thirty years ago, there were three acids whose composition was unknown, namely, the muriatic, the boracic, and the fluoric. Although the latter is still undecomposed, the boracic acid has followed the general analogy, having yielded a new combustible body, boron, united to oxygen. The muriatic acid is now believed to be composed of hydrogen and chlorine. Sulphuretted hydrogen has most of the propertes of an acid, but contains only sulphur and hydrogen; the hydriodic acid consists of iodine and hydrogen, and the prussic acid of carbon and nitrogen, united to form a compound base, which is however not acid, until it unites with hydrogen. Thus, there are four* acids in which hydrogen appears to be essential to the acidity, and oxygen is not present; while the bases of three of these acids, namely, sulphur, iodine, and chlorine, form other acids, by uniting with oxygen; and even the compound basis of the prussic acid, consists of elements which, individually, form acids with oxygen.

Some chemists are now inclining to the opinion, that no one principle can be regarded as being endowed with the peculiar prerogative of being an acidifier, but that acidity may, and often does arise from a balanced or conjoined effect of several principles.† Oxygen exists, as we have seen, in all the alkalies, except ammonia, and in all the earths and metallic oxides, so that we cannot attribute to it the exclusive property of producing either acidity or alkalinity, although it is in most instances concerned in both; still, that body without which another would not be acid, must be considered as its acidifier.

Most of the acids that have been discovered, are of very little importance; but several of the principal acids are eminently valuable, and their history, being equally instructive and interesting, will be developed with sufficient detail, in connexion with that of the inflammable bodies that form their bases. In giving the history of the principal acids, I shall therefore pursue the synthetical course, as being the most convenient and intelligible, although the analytical was, for the same reasons, adopted in the account of the alkalies and earths; or, in other words, the bases of the most important acids will be presented first, whereas those of the fixed alkalies and earths were presented last.

---

* Besides others of a most doubtful character, as that composed of hydrogen and tellurium.

† For an ingenious discussion of this view, see Murray's Elements, 6th Ed. Vol. II, Art. Acids. Mr. Murray is inclined to think that even the water, usually regarded as combined with acids and alkalies, acts rather by its elements, than in the character of water, a fact which it may be difficult either to prove or disprove.

GENERAL PROPERTIES OF ACIDS.—THEIR NOMENCLATURE.

1. Most of them sour.
2. Soluble in water; most of them largely—some very sparingly.
3. Redden most of the vegetable blues—restore the colors that have been changed by alkalies or alkaline earths.
4. Combine with alkalies, earths, and other metallic oxides, and form salts.
5. The stronger acids corrosive.
6. They consist generally, of an inflammable base, combined with oxygen; in a few cases hydrogen takes its place.*
7. Exist solid, fluid and gaseous, in different cases.

NOMENCLATURE OF THE ACIDS.

(*a.*) In the new or French nomenclature, acids are named from the inflammable bases.

(*b.*) The termination *ic* denotes the higher combination with oxygen; *ous*, a lower, and the proportions in both are definite.

(*c.*) Where there is only one proportion of oxygen the termination is in *ic*.

(*d.*) Where the base is complex, as in the animal and vegetable acids, the termination *ic* means nothing, and the acid is usually named from the substance which affords it; as tartaric acid, from tartar, &c.

(*e.*) The names of the hydracids, as they are called, terminate in *ic*, as hydrochloric, hydriodic, &c.

SULPHURIC ACID.

1. NAME.—*Derived from sulphur*, the inflammable base, which affords also other acids. Oil of Vitriol is the name of the shops.†

2. HISTORY.—Discovered by Basil Valentine, *at the close of the 15th century.*

3. EARLY PROCESS.—*By distilling sulphate‡ of iron*, (copperas,) whose water of crystallization, amounting to about one half its weight, had been previously dissipated by a moderate heat. This process is still followed in Saxony; 600 lbs. of copperas gave Bernhardt but 64 of the acid, and when no water was put into the receiver, 52 pounds of a dry concrete acid were obtained, formerly called glacial oil of vitriol. Glauber says that sulphate of zinc affords a purer and better acid, and with less heat.§

---

* Sulphuretted hydrogen and prussic acid, consist wholly of combustible elements. Chloric acid is composed of two supporters of combustion and some would refer the oxiodic and the chloriodic acids to the latter class.

† Because it was distilled from green vitriol, and has an oily consistence; it was called spirit of vitriol, when it was less concentrated.

‡ It is the sulphate of the protoxide, which passes to the condition of peroxide.

§ Parkes' Essays, Vol. I. p. 468.

4. MODERN PROCESS.[*]

(*a.*) *Carried on in chambers, lined throughout, with sheet lead;* usual size, 20 feet long, and 12 wide—or 40 to 60 by 16 or 18; in one case, in England, 120 by 40, and 20 high—contents 96000 cubic feet.

(*b.*) *Sulphur,* 7, 8 *or* 9 *parts, coarsely bruised, and* 1 *part of common nitre, are mixed.*—One pound of the mixture for every 300 cubic feet of air, is placed in separate portions upon iron or leaden plates, supported by stands of lead. The sulphur is lighted by a hot iron and the door closed.[†] The combustion continues 30 or 40 minutes, and in three hours the acid gas is absorbed by the water on the floor of the room, which is usually about six inches deep; or sometimes the acid vapors are carried by the current of air that supports the combustion, into another leaden room, where they are condensed by water.[‡]

(*c.*) *The room is then ventilated,* and the process repeated every four hours, day and night, until the water at the bottom is sufficiently acid.

(*d.*) *Then it is drawn off by a syphon,* into a leaden reservoir.

(*e.*) *It is pumped from this into leaden boilers,* and there concentrated[||] by heat, until it is of the sp. gr. 1.350 to 1.450, or 1.560.

(*f.*) *It is finished in glass retorts,* placed in sand baths, and the retorts are now generally furnished with platinum wire to prevent the concussion in boiling; water, and nitrous and sulphurous acid gas being expelled, it then has the specific gravity 1.850, or, as Dr. Ure says, 1.842, if pure. For economy, the concentration of sulphuric acid is now often performed in platinum boilers, placed within iron ones of the same size and form.

The conversion of sulphur into an acid,[§] is easily proved by burning it in a pendent metal spoon, introduced into a bottle of oxygen or common air, on the bottom of which is some litmus infusion.[§]

5. PROPERTIES.

(*a.*) *Thick, oily looking fluid;* pours slowly from vessel to vessel; corrosive, and, with or without heat, destroys all animal and vegetable bodies; the first sensation when it is rubbed on the skin, is that of lubricity, but immediately after, there is extreme burning.

---

[*] Begun by Dr. Ward, in England, before 1746, by combustion in glass bells or globes; in 1746 Dr. Roebuck introduced the leaden chambers at Birmingham.—Parkes' Essays, Vol. I, p. 476.

[†] A red hot cannon ball is sometimes rolled in through a trough lined with iron.

[‡] The theory of this process cannot be fully elucidated until we have become acquainted with the nitric compounds, when it will be resumed. It may be stated, however, that sulphurous acid is formed from the sulphur, and nitric oxide gas from the nitre; this obtains oxygen from the air, becomes nitrous acid vapor, then oxygenizes the sulphurous acid, and turns it into sulphuric acid.

[§] The sulphurous.

[||] Concentration is when a volatile ingredient is driven off, and a more fixed one is saved.—Distillation when the volatile ingredient is saved.

(*b.*) ***When pure; colorless***, limpid, inodorous; intensely sour, even when largely diluted with water.

(*c.*) *Sp. gr.* as already stated, 1.850,—or (Ure,) 1.842; according to Dr. Thomson, 1.847; if heavier, it may contain sulphate of lead, or sulphate of potash, or both; 2½ per cent. of sulphate of potash gives it the sp. gr. of 1.860, and Dr. Ure states* that the best acid of commerce contains from ½ to ¾ of 1 part in 100, of foreign matter, which is sulphate of lead, in the proportion 4, to sulphate of potash 1.†

(*d.*) ***Its purity is decided by saturating it by an alkali.***—Dry carbonate of soda, 100 grains, neutralizes 92 grains of pure liquid sulphuric acid, and 100 of the acid require 108, or 108.5 of the carbonate.‡—***Henry.***

(*c.*) ***Produces heat, when mingled with water in every proportion;*** 4 acid +2 water=300° Fahr.; or better, 2⅔ acid to 1 water, or by measure, 1⅔, or 1½ acid to 1 water.§

Place a thin glass tumbler in a dish—pour in the water—provide a thin glass tube, 8 or 10 inches long, and fill it two thirds with colored water, add the acid in a slow stream, stirring with the glass tube, and soon after, the water in the tube will boil, and another tube, filled with alcohol, will also be made to boil.

Explanation.—Inorease of specific gravity, and diminution of capacity for heat.

Two by measure, of acid +1 of water, starting from 50°=300°, and the concentration $=\frac{1}{13}$.

(*f.*) ***With ice.***—Ice 1+ acid 4=212°.
ice 4+ acid 1 produce intense cold.

In both instances, the affinity of the acid for the water produces fusion, as the two cannot unite while the water is solid. The excess of acid then goes, in the first case, to produce heat with the water formed; in the second case, there being no more acid than is wanted for the fusion, cold is produced, upon the general principle that fluidity requires heat, and that the absorption of heat produces cold.

(*g.*) ***Absorption of water from the air.***—Rapid, especially if exposed with a large surface; in one day 3 parts became 4, and 1 oz. in twelve, months gained 6½; a drachm gained in five successive days, 68, 58, 39, 23, and 18 grains, and in five days more only, 5, 4, 3, 4; in one case, in fifty six days a drachm became 6½ drachms.

---

* Dict. 2d Ed. p. 91.

† The acid of commerce often contains 3 or 4 per cent. of salts, and sometimes more arising from the use of nitre, to remove the brown color; evaporation in a platinum dish gives a prompt result, and if there are more than 5 grains in 500, the acid is sophisticated.—*Ure.*

‡ These numbers do not correspond with the equivalents of sulphuric acid and carbonate of soda, as they stand in our modern works. 100 acid should neutralize very nearly 110 of carbonate soda. (49 liq. sul. acid : 54 carb. soda : : 100 S. A. : 110.2 C. S.)—*Communicated.*

§ Seventy three acid to twenty seven water, or very nearly 3 acid to 1 water.—*Ure.*

(*h.*) *Discoloration from the air, &c.*—All common combustibles, even the floating dust in a room, will discolor this acid; a drop of oil of turpentine does it instantly; it is decomposed by the acid, and carbon developed.

(*i.*) *The pure acid is not rendered turbid by dilution with water.*—The impurities are chiefly sulphate of potash, and sulphate of lead; the latter being very insoluble, is precipitated, renders the acid milky, and in time subsides; hence dilution is a means, to a certain extent, of purifying the acid.[*]

(*j.*) *The acid is purified by distillation.*—Dr. Ure's method is good, and avoids the danger which was encountered in the old way. *Arrangement.*—A retort of from 2 to 4 quarts capacity; acid 1 pint, adopter 3 or 4 feet long, terminating in a large receiver; apply a charcoal fire to the naked retort, which should contain along with the acid, a few pieces of broken glass, or some platinum wire,[†] or platinum foil, which will prevent the heavy recoil upon the glass, produced by the sudden condensation of vapor, and by the great weight of the fluid.

(*k.*) *Boiling point.*—Acid of sp. gr. 1.850 containing 81 per cent. real acid, boils at 620°, and at a lower temperature, in proportion as it is mingled with more water; that of sp. gr. 1.849, boils at 605°, and contains 80 per cent real acid; that of sp. gr. 1.838 containing real acid 75 per cent. boils at 530°, &c. It is rendered stronger by heating, until the acid itself rises in vapor, and if mingled with combustible matter, this is burned off by heating it.

(*l.*) *The freezing point.*—This depends on the dilution of the acid. If of sp. gr. 1780,[‡] it congeals at 45°; viz. with 13 degrees less than causes water to freeze; it freezes at 32°, if any where between 1.786, and 1.775; if 1.843, or like that of commerce, it freezes at—15°; and if half water, at—36°.

When once frozen, it does not easily melt; it sometimes forms regular prismatic crystals.[§]

(*m.*) *Effects on the test fluids*, the same that were mentioned under the general properties of acids; infusion of litmus is very sensible, and that of purple cabbage sufficiently so; alkanet tincture, previously blued by a little ammonia, is instantly turned red again by a drop of the diluted acid.

---

[*] Dr. Ure, by evaporating 100 parts of sulphuric acid, in a platinum dish, obtained three quarters of a part of solid matter, of which 2 (4 ? p. 309, *c.*) was sulphate of potash, and 1 sulphate of lead.—Jour. Science, Vol. IV, p. 115.

For a table of the boiling point of acid of different densities, see Henry, Vol. I, p. 386, and Eng. Jour. Science, Vol. IV, p. 127.

[†] I have found it to succeed well without this precaution, which, however, it might be advisable to take.

[‡] Easily brought to this specific gravity by mingling 6 1-8 parts of the acid of commerce with 1 1-8 of water.—Thomson's First Principles, Vol. I, p. 214.

[§] See Am. Jour. Vol. VI, p. 186.

6. DECOMPOSITION.

(*a.*) Driven in vapor through a red hot platinum tube, or a small tube of glass or porcelain, this acid is decomposed, and affords sulphurous acid gas, two volumes, and oxygen gas one volume.

(*b.*) Its decomposition is best effected upon one of its salts, as will be mentioned under sulphate of baryta, from which we can obtain the sulphur.

(*c.*) Heated with charcoal powder, it is decomposed, and various gases are evolved, as will be mentioned farther on.

(*d.*) When it chars any animal or vegetable substance, it suffers decomposition.

(*e.*) Decomposed by galvanism—sulphur appears at the negative, and oxygen at the positive pole, platinum wires being used.

(*f.*) By being passed through an ignited porcelain tube along with hydrogen, which unites with its oxygen and precipitates the sulphur, and perhaps evolves sulphurous acid gas.

7. PROPORTION OF ITS CONSTITUENTS AND COMBINING WEIGHT.

(*a.*) *Centesimal ratio.*—Writers vary between 43.28 sulphur, and 56.72 oxygen, and 40 sulphur and 60 oxygen. Dr. Wollaston admits the latter numbers, and Berzelius those that approximate to them; 40 and 60 are probably correct.—*Murray.*

(*b.*) *Equivalent numbers.*—The proportions of 40 and 60, correspond with 16 of sulphur, 1 proportion, and 24 of oxygen, 3 proportions, making 40 for the representative number of the dry acid, and liquid sulphuric acid = 1 real acid, 40, and 1 of water 9=49.

It is supposed that by volume, the sulphur would be represented by 100, and the oxygen gas by 150, for oxygen gas is considered as combining in the proportion of half a volume which would be 50, if the 1 proportion of sulphur is called 100, and there are 3 of oxygen, which would of course be 150.

8. ANHYDROUS ACID.

(*a.*) The dark fuming acid, already mentioned as being obtained by distilling green vitriol, has a sp. gr. of 1.896 or 1.90, and boils from 102° to 122° Fahr.

(*b.*) Heated in a glass retort to which a receiver is attached, surrounded by snow and salt, half of the acid passes over in a state resembling asbestos, and is regarded as sulphuric acid without water, or the anhydrous acid, and the acid remaining in the retort is like the common oil of vitriol, composed of acid one proportion, and water one.

(*c.*) It is the pure acid without water.

(*d.*) It smokes violently when exposed to the air, and is dissipated too speedily to admit of being weighed. It is less corrosive than common sulphuric acid. It crystallizes in tough silky filaments like asbestos, or in flat transparent rhomboids, of which the large angles are but little above 90°.

Thrown into water, it acts like red hot iron.

It liquifies at 66°, is more fluid than the common acid, and has a specific gravity of 1.97.

9. IMPORTANCE AND USES OF SULPHURIC ACID.

(*a*.) Largely used in chemistry, being the most common agent in decompositions, where other acids are to be separated from their combinations.

(*b*.) For generating hydrogen, with the aid of zinc or iron, and water, for filling balloons.

(*c*.) For the manufacture of soda water, to evolve the gas from marble powder.

(*d*.) For manufacturing nitric, muriatic, citric and tartaric acids.

(*e*.) In dyeing, bleaching, cleaning metals from oxide, and in preparing chlorine for disinfection.

(*f*.) In forming metallic sulphates, as those of copper, zinc, and iron; in making calomel, and corrosive sublimate, and sulphuric ether; in dissolving indigo, extracting phosphorus, &c.

(*g*.) In medicine, largely diluted—50 or 60 parts of water to 1 of acid.* Used as an antifebrile drink, and as a tonic and stimulant. It is also used externally as a caustic, and in the composition of elixir vitriol, &c. Externally, as a gargle in putrid sore throats, and apthous mouths, and as a wash in cutaneous diseases. In its concentrated state, it is a violent poison, and the person who swallows much of it, dies in agony; chalk and carbonate of magnesia, are the best remedies.

10. DIFFUSION IN NATURE.

Largely in combination, as in the earthy and metallic sulphates, but not much known in a free state; occurs in that condition in the crater of a volcano at Mount Idienne, in Java, &c.; also, observed by Baron Humboldt, in the river Vinagre, in the Andes of Popayan.†

Found in the cavities of a small volcanic hill, called Zoccolino, near Sienna; also, in the state of New York.‡

11. TEST.—*Muriate of barytes;* it acts by giving its earth to this acid, and by thus taking it from every combination, it affords us an infallible test for the sulphuric acid; the precipitate is a heavy white powder.

12. POLARITY.—*Electro-negative;* it is attracted to the positive pole in the galvanic series.

---

* Or, as much as will make it agreeable, and it may be qualified with sugar. To prevent its injuring the teeth, it is usual to suck it through a quill, but a glass tube would be better.

† Boston Jour. Vol. II, p. 460. ‡ By Prof. Eaton—Am. Jour. Vol. XV, p. 23.

Remark.—According to Berzelius, a minute quantity of titanium exists in the English acid, and of tellurium in that of Sweden.

SULPHUROUS ACID.

1. HISTORY.

This gas being produced whenever sulphur is burned, it has probably always been known, although it was not recognized as a distinct chemical agent, until noticed by Stahl; but it was first obtained pure by Dr. Priestley.[*]

2. PREPARATION.

(*a.*) *In a glass globe or bottle, burn sulphur in common air*, either in a pendent spoon,[†] or by means of a sulphur match; sulphurous acid gas will be formed, and if there be litmus or cabbage infusion in the bottle, it will be reddened, and eventually the color will be destroyed.

(*b.*) *The same result is obtained with oxygen gas;* the combustion is brilliant, with a blue and white light, and the product is entirely sulphurous acid. There is no change in the volume of oxygen gas, but the weight is doubled.

One volume of sulphur vapor unites with one volume of oxygen.

(*c.*) *Red oxide of mercury and sulphur*, equal parts, or sulphur 12, and peroxide of manganese, 100 parts, mingled in powder and heated, produce sulphurous acid gas; in the former case, one cubic inch is obtained for every 5 grains of the oxide; the latter process is recommended as being a very good one.

(*d.*) *The best process is, by mercury* 1 *part, with* 6 *or* 7[‡] *of sulphuric acid*, in a small glass retort; apply the heat of a lamp or of a few coals, and obtain the gas over mercury, or by a recurved tube passing to the bottom of a jar or bottle, and displacing the common air, as exhibited in the figure on p. 232, only substituting an empty bottle for the bottle of water—theory, the mercury detaches 1 proportion of oxygen, and leaves the whole of the sulphur combined with the remaining two proportions of oxygen, and thus evolves the sulphurous acid gas; the sulphate of mercury which is formed, may be saved for future use.

(*e.*) *Sulphuric acid is decomposed by many other things;* it may be boiled on charcoal, wood, straw, cork or almost any vegetable substance, and sulphurous acid gas will be obtained; but there are other gases produced, and the process is much less neat than when mercury or copper is employed; tin answers equally well.

---

[*] On Air, Vol. II, p. 1.

[†] Pendent spoons are easily made by cutting a slip of sheet copper, into the form of a very acute isosceles triangle, the sharp end may be thrust through a cork, and the other be hammered into a spoon and turned at right angles.

[‡] Metal 2. acid 3. (Turner,) with so small a proportion of acid, there might be danger of breaking the retort; it is better to use an excess of acid which can be afterwards poured off. Thénard directs 6 or 7 of acid to 1 of mercury.

3. COMPOSITION AND PROPERTIES.

(*a.*) Sulphurous acid gas is composed of 1 volume of sulphur in vapor, and 1 volume of oxygen condensed into one volume,[†] or we may say that the volume of the oxygen gas is not changed, but an equal weight of sulphur is added to it.

Its sp. gr. being 2.22,[*] and that of oxygen gas 1.11, therefore the weight of the gas is divided equally between the oxygen, and the sulphur.

(*b.*) 100 *cubic inches weigh nearly* 68 *grains;* accurately, it should be 67.776 grains, containing 33.888 of sulphur, that is, just half.[‡]

(*c.*) *It is fatal to life*, producing spasms of the glottis, and killing both by suffocation and excoriation; used to destroy bees.[§] Intolerably suffocating, disgusting, and distressing, even when breathed in moderate quantity, and mixed with much air; it creates a cough and a stricture of the breast.

(*d.*) *Extinguishes combustion;* best shewn by a pendent candle let down into a jar of the gas, as exhibited in a note to p. 187; it may be extinguished many times, and then the gas may be poured upon other candles, and will run down like water and extinguish them.

(*e.*) *Fugaciously reddens, and soon bleaches the dark vegetable colors.*—A red rose becomes white in it, as may be beautifully shown by holding a red rose over a burning sulphur match, when it will become first variegated and then white, and immersion in water restores the color; litmus paper is first reddened and then becomes white. The color is not decomposed, for it can be restored by a stronger acid or by an alkali.—*Turner.*

(*f.*) *The aqueous solution is prepared by passing the gas*, with a recurved tube, *through water*, which, when kept cold by snow, absorbs 33 times its volume;[‖] or 100 grains absorb 8.2 of the gas.

(*g.*) *The gas is spontaneously disengaged* into the air; rapidly by sulphuric acid.

(*h.*) *Sulphuric acid, saturated with the sulphurous, crystallizes* with a moderate reduction of heat; when distilled, it crystallizes and becomes solid.

(*i.*) *Not decomposed by heat.*

---

[*] 2.234, Thénard—2.25, Th. and G.-Lus.

[†] Thomson's First Prin. I. 216.

[‡] Ann. de Chim. et de Phys. Vol. V.

[§] A gratuitous cruelty, as they can be transferred to another hive, and thus, both the bees and the honey can be saved.

[‖] At 61°.—*Ure.*

(*j.*) If two measures of sulphurous acid gas and one of oxygen be mingled in a jar, standing over mercury, and a little water be added, sulphuric acid will be formed; the same result is obtained by passing the mixed gases through a red hot tube, or causing the electric spark to pass through them.

(*k.*) *Becomes liquid by great cold;* or by moderate cold, —31°, if aided by pressure.

(*l.*) Decomposed when passed over ignited charcoal, or with hydrogen, through a red hot tube; water and sulphur are the products

(*m.*) Liquid sulphurous acid does not give up its gas by freezing, and becomes so heavy as to sink in water.

(*n.*) Boiling expels the gas, although the water remains acid, from the formation of sulphuric acid.

(*o.*) Exposed to the air, the liquid acid becomes slowly sulphuric acid, absorbing oxygen gas from the air; its smell is like that of the gas.

(*p.*) *Decomposed, by potassium*[*] *heated in it;* products, probably potassa and sulphuret of potassium; also, at ignition, by hydrogen, forming water and leaving sulphur; and by carbon, producing carbonic acid and carbonic oxide, and liberating sulphur.

(*q.*) *Sulphurous acid attracts oxygen powerfully;* it converts the peroxide into the protoxide of iron; the same with manganese, and it precipitates gold, platinum, and mercury in the metallic state, because their affinity for oxygen is feeble; it becomes itself, in the mean time, sulphuric acid, by acquiring one proportion of oxygen.

(*r.*) *Condensation of sulphurous acid gas.*—Mr. Faraday,[†] by confining, in a bent glass tube, both sulphuric acid and mercury, and applying heat, caused the sulphurous acid gas which they produced by their reaction, to pass into the other end of the tube, cooled by a freezing mixture, and thus obtained the sulphurous acid in a liquid state. The pressure was about two atmospheres.

(*s.*) *Mr. Bussy*[‡] *also obtained the liquid anhydrous acid,* from the above named materials, by passing the dried gas into a vessel cooled by ice or snow, then through a tube containing melted muriate of lime, and finally into a matrass surrounded by a mixture of ice 2 parts and common salt 1; in this, the gas is condensed into a liquid, at the common atmospheric pressure.[§]

---

[*] It is decomposed in the same manner by sodium.

[†] Phil. Trans. 1823, p. 190.

[‡] Ann. Phil. Vol. VIII, p. 307, N. S.

[§] M. A. de la Rive (Bib. Univ. Mars, 1829, and Am. Jour. Vol. XVII, p. 166,) directs, that a second tube, filled with muriate of lime, should pass from the second to a third vessel cooled like the others, and from this a tube may proceed to the mercurial cistern. The junctures must be luted tight. The gas having been disengaged during 8 or 10 hours, white crystals, (hydrates) are found in the vessel No. 1; they resemble the hydrate of chlorine; they are said to remain solid at 4° or 5° (*centigrade;*) and in Nos. 2 and 3, is the liquid sulphurous acid, which must be immediately (*i.*) Sir H. Davy, substituting the pressure of the vapor of ether for that of the gas itself, and causing the former, through the medium of mercury in the bend of the tube, to press upon the latter in the other leg, while cold was applied, succeeded in condensing the sulphurous acid into a fluid.*

4. Properties of the liquified gas.

(*a.*) *Limpid, colorless,* refractive power similar to that of water; when the tube was opened it evaporated rapidly, but without explosion.

(*b.*) *Sp. gr.* 1.45—*boils at* 14° *Fahr.* and evaporates rapidly, but without explosion, cooling the residuary fluid to 0, so that it remains some time liquid under the pressure of the atmosphere.

(*c.*) *No visible fumes, but a strong smell of sulphurous acid,* eventually leaving the tube dry.

(*d.*) *Ice* dropped into the fluid, proved so much warmer, that the ice *made the fluid boil.*

(*e.*) *Mercury is frozen by* the cold produced by the *evaporation of sulphurous acid;* for this purpose the ball of a thermometer tube is surrounded with cotton, and kept wet with the liquid.

(*f.*) By its aid, and that of a moderate pressure, several additional gases have been liquified.† The cold was carried to −60°, but absolute alcohol and ether did not freeze. One part of the acid in a watch glass, freezes, by the spontaneous evaporation of the other.

5. Combining weight.

Sulphurous acid consists of 1 proportion of sulphur 16,+2 of oxygen 16=32, which is therefore its equivalent number.

6. Polarity.—Like other acids, *it is electro negative,* as it is attracted to the positive pole in the galvanic arrangement.

7. Sulphurous acid in volcanos and solfaterras.—It is constantly emitted wherever volcanic fires are active. This arises from the combustion of sulphur, raised by the subterranean heat, and burned by the air in its passage. Those who visit volcanic craters and solfaterras are constantly incommoded by this gas, and often find it necessary to mount some elevation in order to escape from suffocation.

---

corked tight, and the vessel must be constantly surrounded by a freezing mixture, else the gas will escape, or the vessel explode. A few drops of the liquid sulphurous acid thrown upon water, produces a crust of ice.

If mercury, of the volume of a hazlenut, is moistened by a few drops of the acid, and the apparatus placed under an exhausted receiver, the metal will freeze solid, and a considerable mass may be thus frozen and preserved for a few minutes. It is found that solid mercury is a much better conductor of electricity than the fluid metal. In its pure liquid state, it was not decomposed by electricity, but if a little water was added, sulphuretted hydrogen appeared at one pole, and oxygen at the other.

* See Faraday's Chemical Manip. p. 205. † Ann. Phil. N. S. Vol. VIII, p. 307.

8. Uses, in bleaching, *and for other purposes.*[*]

(*a.*) *It bleaches straw, woolen and silk, and gives silk lustre.*—Sulphur is burned in a barrel, in family operations; the articles to be bleached are hung up in the barrel, and moistened with water or solution of pearlashes.[†] It also discharges iron moulds and vegetable stains from linen. For this purpose, the places must be made thoroughly damp, and then two or three sulphur matches must be burned close to them; liquid sulphurous acid will thus be formed, and the spots will soon disappear.

(*b.*) A similar process is practised on a large scale in the arts; the sulphur is burned in chambers lined with sheet lead, and the moistened articles are hung upon frames.[‡]

(*c.*) Prepared of a proper strength for liquid bleaching, by distilling in a glass retort 1 lb. of wood shavings, with the same weight of sulphuric acid, and placing two gallons of water in the receiver; if to be used to stop the fermentation of wine, only two quarts of water are placed in the receiver.

(*d.*) A rag, imbued with sulphur, is sometimes burned in cider casks to preserve the cider from too rapid fermentation.

(*e.*) The fumes of burning sulphur, (or in other words, sulphurous acid gas,) were employed 1600 years ago in bleaching wool; but the gas whitens only the surface, and therefore the liquid acid is preferred.

(*f.*) Thénard says[§] that the sulphurous acid is beginning to be used to cure diseases of the skin—that there are in various hospitals in Paris, baths of this kind—that a few applications suffice to remove psora, and that the tetters yield to the continued use of this remedy. It is said that Dr. Gulès, of Paris applies[‖] the vapor of burning sulphur mixed with air, to the surface of the body, as an air bath, with much advantage in many chronic diseases of the joints, the glands, and the lymphatics.—*Ure.*

* * * * * * *

Dr. Torrey informs me that he has made the liquid sulphurous acid before his class, and that tubes of it may be sealed by the blowpipe, while immersed, (except the capillary extremity,) in a freezing mixture.

The hypo- or sub-sulphurous, and the hypo- or sub-sulphuric acids will be mentioned after the sulphates and sulphites.

---

[*] See Parkes on Bleaching. Essays, Vol. II, p. 337.

[†] Water would probably be better, as the alkali would neutralize a part of the acid gas, and withdraw it from action.

[‡] Verbal communication to the author while in England, from a manufacturer.

[§] Fifth Ed. VII, p. 196.

[‖] In an apparatus called Boite Fumigatoire.

SALTS.

Introductory Remarks.

That the student may not be fatigued by a too frequent reiteration of similar properties, the history of saline bodies will be given, in divisions, under that of the acids, which they respectively contain, in the same manner as that of the principal acids is given, under combustibles.

We shall thus dispose of the salts in convenient groups, and the most important will be brought into view, as early as possible.

As many of the salts are unimportant, the history of some of them will be abridged, and that of others omitted, or included in a general statement of the properties of the genus to which they belong. Some of the salts are, however, eminently important and interesting, and therefore the history of such salts will be developed, with all the necessary details. Under the head of attraction and crystallization, many things have been stated respecting saline bodies, which need not be repeated here, and various generalizations will be prefixed to the first genus. It remains, to make a few other observations, by way of introduction to the history of saline bodies generally.

As salts consist of acids and salifiable bases; alkalies, earths, and metallic oxides, we observe that the powers of saturation differ very widely among these agents; it takes much more of some bases to saturate a given acid than of others, and vice versa, of different acids to saturate a given base. This evidently depends upon the number expressing the combining powers of those different bodies; or rather the formation of salts is only a mode of ascertaining and expressing this very fact, in relation to acids and bases. For instance, the combining power of nitric acid is expressed by 54, that of lime by 28, and that of baryta by 78; to form then anhydrous nitrate of lime, 54 parts of nitric acid will unite with 28 of lime, and the chemical equivalent of nitrate of lime will be $54+28=82$; but to saturate 54 of nitric acid, requires 78 of baryta, and therefore the chemical equivalent of nitrate of baryta will be $54+78=132$.

Now, suppose lime and baryta to be combined, each with two acids; say the nitric and the sulphuric; the numbers expressing the combining powers of these earths being as above stated, and that of sulphuric acid being 40, the sulphate of baryta will be expressed by $40+78=118$, and that of the sulphate of lime by $40+28=68$, the salts being supposed anhydrous. It was suggested by Berthollet, and the idea was adopted, more or less, by many chemists, that the strength of affinity is inversely as the saturating power; but this idea is inconsistent with facts; e. g. 40 parts of sulphuric acid require 28 of lime and 78 of baryta for saturation, and therefore baryta should attract sulphuric acid less powerfully than lime, which is not true.

Triple Salts are those which have two bases united to one acid, as the phosphate of soda and ammonia; this may be regarded as two phosphates combined, or as a phosphate of two bases; some prefer to call such combinations double salts.

Neutral Salts were formerly regarded as those in which the properties of the acid and base are both entirely lost, as in sulphate of potassa; but sometimes there are peculiar characters imparted by the acid or base, more commonly by the latter; e. g. the salts of ammonia are volatile; of magnesia bitter; of alumina styptic; and of glucina sweet. The nitrates are cooling, and they deflagrate with red hot charcoal. In general, a salt is said to be insoluble, if it requires 1000 parts of water for its solution.

Salts are not only compound bodies, but the acids and bases of which they consist, are also compound. Thus, in sulphate of soda, the acid is composed of oxygen and sulphur, and the base of oxygen and sodium. It has been imagined by some, that in salts, the elements, losing the form of acids and bases, are directly united to each other, so as to produce ternary or quaternary compounds. Thus, in sulphate of soda, the oxygen, which exists in the acid, in the base, and in the water of crystallization; the sulphur of the acid; the sodium of the base, and the hydrogen of the water, are regarded as being in immediate union, to form a quaternary compound; but of the truth of this speculation there is no direct proof; and it is extremely improbable that it is true, because the acid, the base and the water can be combined synthetically, to form the salt; the water can be expelled by heat and recovered, and the galvanic power will separate the acid and alkali unaltered, in full proportion, and we know not of any affinity which should unite these bodies in a quaternary combination, and then resolve them again into binary compounds.

NOMENCLATURE AND CHARACTER OF SALTS.

1. *As almost every acid unites with nearly every base,* and sometimes in more than one proportion, it follows that the salts are very numerous.

2. *They are said to exceed* 2000, although not more than thirty were known fifty years ago.

3. *The old names were sometimes barbarous, absurd, or false,* implying incorrect ideas.

4. The nomenclature of the French chemists,* is eminently useful in the study of the salts.

5. *Every salt consists of an acid and a salifiable base,* and the bases, except ammonia, are all oxides of metals or of inflammable bodies.

---

* See page 35.

6. *The genera are derived from the acids; the species from the bases*, thus all that contain sulphuric acid are sulphates; all that contain nitric acid are nitrates, &c.

7. *The bases are the oxides*[*] of which there are three divisions; the alkalies, the earths, and the other metallic oxides.

8. *Every base that combines with acids, furnishes a species;* thus sulphuric acid with potassa, soda, and ammonia forms a sulphate of each of those bases.

9. The termination *ate*, corresponds with the acid, whose termination is in *ic*, and the termination *ite*, with the acid whose termination is in *ous;* thus, sulphuric acid gives sulphates; sulphurous acid sulphites.

10. There are some acids containing less oxygen than those that terminate in *ous;* in such case, the word hypo is prefixed; thus we have hypo-sulphurous acid, hypo-nitrous acid, giving also salts that are called hypo-sulphites, and hypo-nitrites.

11. It was formerly supposed, that there is sometimes an excess of acid in a salt, in which case, the preposition *super* or *hyper* was prefixed; and on the other hand, that there is, in particular cases, a deficiency of acid or an excess of base, and then the preposition *sub* was prefixed; thus, there was a super-sulphate of potassa, and a subcarbonate of potassa.

Now, salts with excess of acid are distinguished by the prefix, *bis* or *bi;* thus we have *bi*-sulphate and *bi*-carbonate of potassa; because in these salts, there is just twice as much acid as in the carbonates of the same base. In some salts, the double proportion is again doubled, and then the word *quadro* is prefixed; thus there is oxalate, *bin*-oxalate and *quadr*-oxalate of potash, implying one, two, and four equivalents of the acid to one of the base. The word *super* is now banished from the nomenclature of salts;[†] but *sub* is still retained by some, where there are two or more proportions of the base. But, Dr. Thomson[‡] has proposed to use the Greek numeral words, *dis*, *tris*, *tetrakis*, to denote the proportions of base in a sub-salt; thus, *di*-sulphate of alumina contains one proportion of acid and two of the earth, but this nomenclature has not yet obtained general currency.

12. *Salts are generally, but not always sapid.*—The first idea was derived from common salt; but many earthy salts are insipid, e. g. sulphate of lime, carbonate of lime, &c. and such salts are generally insoluble.

13. *Salts are generally, but not universally soluble in water;* the alkaline salts are all soluble, but earthy and metallic salts have sometimes one character and sometimes the other. A salt is said to be

---

[*] Ammonia excepted.

[†] It may be, and often is still used in a vague and popular sense.

[‡] Dr. Thomson has introduced the word *sesqui*, where there is supposed to be a half of an equivalent.

insoluble, if it requires more than 1000 parts of water for its solution.

14. *Incombustible*, with a few exceptions.

15. *Crystallizable*, either by natural or artificial processes.

16. *Saturation* between acid and base is *determined*—

(*a*.) *By the taste*, which, when there is one equivalent of each, becomes saline, or at least, ceases to be acid or alkaline.

(*b*.) By the absence of any *effect on test colors*.

(*c*.) In the case of a carbonate; *by the cessation of effervescence*.

(*d*.) A scale or table of chemical equivalents, furnishes at once the information desired, as to the quantity of the one agent necessary to saturate the other.

17. *Salts precipitate, if they are insoluble in water*,* or much less soluble than their constituent principles—

(*a*.) *In powder*, as sulphate of baryta.

(*b*.) *In crystals*, as sulphate of potassa, if formed from concentrated acid and alkali.

18. *If soluble, they remain in solution*, as most alkaline, and many earthy and metallic salts do.

19. The name of a salt expresses its composition, and the knowledge of the composition recals the name.

20. The nomenclature is therefore founded upon the most correct logical principles.

21. *The salts are, on the whole, very important*, to arts, science, and domestic economy. Some of them exist in vast abundance.

SULPHATES OF ALKALIES AND EARTHS.—*General Characters.*

1. Formed by sulphuric acid and a base.

2. Generally crystallizable.

3. Not decomposable by heat, or only partially so, (except the sulphate of ammonia.)

4. Decomposable, (with the same exception,) by ignition with charcoal, being converted into sulphurets.

5. Have generally a bitter taste, if any.

6. Decomposed by all the barytic salts, except sulphate of baryta; the precipitate is insoluble in acetic acid.

7. Precipitated from their aqueous solutions, by alcohol, and in general, crystallized.

SULPHATE OF POTASSA.

1. **Preparation.**

(*a*.) By sulphuric acid and dilute solution of potassa, or of carbonate of potassa, mingled till test paper is no longer affected, or effervescence ceases.

---

* Supposing the bases, or perhaps both acids and bases, to have been previously in aqueous solution.

(*b.*) Evaporation gives regular crystals, whose form is that of six sided prisms, sometimes crowned by six sided pyramids.

2. History.—Long known, and had formerly a multitude of names,* which were banished when it received its present denomination.

3. Properties.

(*a.*) Taste, acrid and bitter—sp. gr. 2.29, or 2.40, easily pulverized.

(*b.*) At 212°, requires five times, and at 60°, sixteen times its weight of water for solution.

(*c.*) Not affected by the air. On burning coals, or red hot iron, it decrepitates.

(*d.*) Contains no water of crystallization.

4. Composition.—Acid, 45.45; potassa, 54.55, or acid, 1 proportion, 40; potassa, 1 proportion, 48 = 88, which is its equivalent number.

5. Decomposition.

(*a.*) *By acids.*—Although the sulphuric acid has a stronger affinity for potassa, than any other acid has, still the nitric and muriatic acids, in large quantities, decompose it in part; the products are much bisulphate of potassa, and some nitrate and muriate of potassa.

Not owing to the capriciousness of chemical attraction, but according to Berthollet, to the influence of quantity, compensating for inferior force of attraction.

(*b.*) By barytic and strontitic water, attracting the sulphuric acid.

(*c.*) Also, by nitrate and muriate of lime, by double elective attraction.

(*d.*) By heating it with charcoal powder, when it becomes a sulphuret, and can be decomposed in the palm of the hand, by vinegar or other weak acid, thus fulfilling Stahl's boast, but not as it was intended by him, that others should understand it.

(*e.*) *Other processes.*—Saw dust substituted for charcoal, and pyroligneous acid for the vinegar, and the acid is afterwards decomposed by heat.—*Dundonald.*

Sulphate of potassa, 100 parts, chalk 100, charcoal 50, heat them—sulphuret of lime is formed, and the alkali being liberated, may be obtained by lixiviation.†

6. Uses, &c.—Called in the shops, vitriolated tartar, and used as a purgative or alterative—dose, half an oz. or less; the effect less transient than that of sulphate of soda. The sal polycrest of the old physicians was made by deflagrating nitre and sulphur, and was a

---

* Vitriolized and vitriolated tartar, sal de duobus, arcanum duplicatum, sal polycrest, salt of Glazer, vitriol of potash, vitriolated vegetable alkali, &c. but vitriolated tartar was the most general name. Hence, and from similar cases, the necessity of the new nomenclature of the salts.

† Ann. de Chim. Vol. XIX.

compound of sulphate and sulphite of potassa. The finest neutral crystals of this salt are obtained when acid predominates in the mixture.

Not found among mineral bodies, but exists in some animal fluids, and in the ashes and juices of some vegetables, as tobacco.*

BI-SULPHATE OF POTASSA.

1. **Preparation.**—By heating together three parts of sulphate of potassa, and one of sulphuric acid; discovered by Rouelle senior; may be obtained in needle formed crystals, and even in six sided prisms.

2. **Properties.**

(*a.*) Soluble in 2 parts of water, at 60°, and in less at 212°.

(*b.*) Melts readily, with the appearance of oil, but becomes of an opake white on cooling; heated for a long time, its superfluous acid is dissipated, and it becomes sulphate of potassa.

(*c.*) Taste acrid; reddens the blue test colors.

(*d.*) The bi-sulphate is usually obtained in the process for nitric acid.

(*e.*) With ice, it generates cold.† Of little use, except to form the sulphate, which is done by neutralizing the excess of acid by chalk; it may be used in crystallizing alum, and is sometimes employed as a flux.

After the process for nitric acid, if the salt, while still fluid, is poured into a pan, it effloresces most beautifully in the course of a few months, presenting a delicate downy coating of crystalline filaments, which make their way over and down the sides of the vessel; if it is glazed, the glazing will peal off and leave the naked biscuit.

It contains two proportions of sulphuric acid, and one of potassa, $40 \times 2 = 80$ acid, $+ 48$ potassa $= 128$ for its equivalent.

SULPHATE OF SODA.

1. **Names.**—Named Glauber's salt, after a German chemist, who discovered it in the residuum of the process for muriatic acid.

2. **Natural history.**

(*a.*) Found in sea water, and in the ashes of marine vegetables, and in kelp.

(*b.*) In the earth, near Astrachan.‡

(*c.*) In salt and mineral springs.

(*d.*) Often effloresces at the surface of the ground, upon the walls of subterraneous edifices and other buildings.

---

* Four. III. 33.

† Four. III, 39.

‡ Kirw. Min

(*e.*) Found in the ashes of old wood, and in some plants, particularly tamarisk.[*]

(*f.*) In large proportion in the Glauberite of Spain.

3. **Preparation.**—By saturating a solution of soda or its carbonate with sulphuric acid, but the quantity produced in the manufacture of muriatic acid, and chlorine, and that can be made from sea water, is much greater than can be consumed.

4. **Properties.**

(*a.*) Crystallizes in transparent six sided prisms, with dihedral summits, usually striated at the edges, and often very irregular.

(*b.*) Taste bitter, and dissolves easily in the mouth; suffers readily, the watery fusion; then dries and melts, with the true igneous fusion.

(*c.*) Effloresces in the air—loses half its weight, and thus becomes, as a medicine, twice as strong; by a high heat, a part of the acid is driven off.

(*d.*) Soluble in 2.67 of water at 60°, and in .8, at 212;[†] in this respect, strongly contrasted with sulphate of potassa. The hot solution of sulphate of soda, crystallizes by cooling,[‡] and when the quantity is great, the crystals are very large, sometimes half a yard in length, and several inches in diameter.[§]

5. **Composition.**—When anhydrous,

Acid,	55.55	or 1	proportion	40
Soda,	44.45	or 1	"	32
	100.			72 its representative number.

---

[*] Jour. III, 42.

[†] In judging of the solubility of a salt, we must not put the salt into water, and expose that water directly to heat, but immerse the vessel containing the salt in a water bath, in which the thermometer is placed.

[‡] At 70°, water dissolves nearly half its weight, twice its weight at 88°, and 3.2 of its weight at 106°, at any higher degree, some of the salt is deposited in opake anhydrous crystals, so that it grows less soluble with more heat.—*Turner*.

[§] If the saturated boiling solution of this salt be made with care in a matrass or flask, and free from agitation, it may be reduced to the temperature of the air without crystallizing. Close the vessel by a stop cock at the top, or a good cork, the instant before it is withdrawn from the fire, and while still boiling. Sometimes on opening or on agitating the solution, and always on throwing in a crystal, (any crystal or solid will do, but better one of the same salt,) nearly the whole fluid will rapidly crystallize, and the temperature will rise considerably. The balance of forces between cohesion and repulsion is disturbed by agitation, or by a crystal affording a nucleus. The pressure of the atmosphere acts only as a disturbing force, and any other disturbing forces produce the concretion; for it happens in vacuo if a crystal be dropped in. Mr. Graham, (Phil. Mag. New Series, Vol. IV, p. 215,) has discovered that a saturated solution of sulphate of soda, placed over mercury, previously heated to 110° or 120°, will cool without crystallizing, but that if a bubble of air, or of any gas, especially of those that are soluble in water, or a portion of any fluid that attracts water, as alcohol, be thrown up into the solution, it will immediately crystallize. Hence it is concluded that the influence of air in causing the crystallization in this well known experiment, is owing to the solution of a portion of it, which thus deprives the salt of a part of its water, and causes the crystallization to begin.

The crystals,

Acid,	24.70	or 1	proportion	=40
Soda,	19.75	1	"	=32
Water,	55.55	10	"	=90
	100.			162 its equivalent number.

6. **Decomposition.**

(*a.*) By combustibles, especially charcoal; the same as that of sulphate of potassa. Immense quantities are produced in making muriatic acid, and in other manufactures; therefore its cheap and effectual decomposition is an object of vast importance for the sake of the soda.

(*b.*) Potassa will do it, but the price of labor forbids, although soda is dearer than potash.

(*c.*) Decomposed (via humida,) by no acid, but it dissolves readily in the nitric, muriatic and sulphuric acids, producing cold. 4 parts sulphuric acid with 5 of this salt produce 47° of cold; 2 parts nitric acid with 2 water and 3 of this, produce more cold than the last mixture; 5 muriatic, and 8 of this salt, form a considerably powerful mixture.

(*d.*) Baryta and strontia decompose it, taking its acid.

Uses.—It is the most common domestic cathartic, and is called *salts*; dose 1 oz. perhaps more, often 1½ oz. Used also in small diluted doses, as a diuretic and aperient. The effloresced salts must be given in half the quantity. It is now used in the manufacture of glass, p. 280 (*b.*)

BISULPHATE OF SODA.

Formed by adding sulphuric acid to a hot solution of sulphate of soda; product, large rhomboidal crystals; efflorescent, soluble in twice their weight of water at 60°; lose their excess of acid by heat.—*Henry.*

SULPHATE OF AMMONIA.

1. **History, Name,** &c.—Discovered by Glauber, who called it *secret sal ammoniac;* other names—*vitriolated ammoniac, vitriolated volatile alkali*, &c. Found in the vicinity of volcanos, and in the waters of the Tuscan lakes; also in the ashes and soot of pit coal.*

2. **Preparation.**—By mingling sulphuric acid 88 parts, and compact carbonate of ammonia 100 parts, to mutual saturation, or by decomposing muriate of ammonia, by sulphuric acid.

3. **Properties.**

(*a.*) The crystals are long six sided prisms, crowned with six sided pyramids; sometimes in plates, silky fibres, or clusters of needles.†

---

* It is not probable that the ammonia exists in the coal, but the nitrogen of the air and the hydrogen of the coal form the ammonia; the oxygen of the air, with the sulphur of the coal, forms the sulphuric acid, and this is doubtless the origin of the sulphate of ammonia in the soot and ashes.

† Four. Vol. III, p. 55.

(*b.*) Taste sharp and bitter.

(*c.*) Solubility at 60° ; water 1, salt 2 ; at 212°, equal parts.

(*d.*) During its solution it produces cold.

(*e.*) Little affected by the air, or slightly efflorescent.

(*f.*) Heated, suffers watery fusion, sublimes in part, and is then sour, and reddens vegetable blues. By a still higher heat, completely decomposed, and resolved into nitrogen, water, and sulphurous acid.

5. Composition.

Acid,	53.1	or	1	propor.	=40
Ammonia,	22.6		1	"	=17
Water,	24.3		2	"	=18
	100.0				75 its equivalent number.

If water be subtracted, it leaves 57 for anhydrous sulphate, which is known only in theory. Dr. Thomson admits but one proportion of water, in the crystallized salt, which would reduce its equivalent to 66.

6. Decomposition.

(*a.*) The nitric and the muriatic acids decompose about ¼ of the salt.

(*b.*) Potassa and soda, baryta, strontia and lime, liberate the gas ammonia, forming a sulphate of the base. Sulphate of soda, and sulphate of ammonia, when mingled, form a triple crystallizable salt.*

(*c.*) Deflagrates with melted nitre, being resolved into water and nitrogen.

SULPHATE OF LIME.

1. Preparation, Natural History, &c.—Formed by the mutual action of diluted sulphuric acid and marble, or chalk, or by the same acid and any soluble calcareous salt, or lime water; the sulphate precipitates.

2. Properties.

(*a.*) Melts before the blowpipe, and in furnace heats.

(*b.*) Solubility in cold water, 500 parts to 1, in 450 at 212°, and crystallizes on cooling. Soluble entirely in dilute nitric acid.

(*c.*) Causes waters to be hard,—decomposing the soap that is mingled with them ; the acid unites with the alkali, and the oil with the earth, to form an earthy soap ; by adding solution of soap to solution of sulphate of lime, this effect is manifested.

(*d.*) Thrown down by alcohol from its aqueous solution.

(*e.*) Decomposed by boiling with baryta, strontia, potassa and soda, and by their carbonates, or at least by those of the fixed alkalies; see those articles.

---

* Th. III, 362.

(*f.*) Insipid and harmless; sp. gr. of the native salt about 2.26 to 2.31.

3. Composition.—According to Dalton, 58.60 acid, 41.40 base. Berzelius and Thomson 58. and 42. Dr. Henry thinks its true constitution is, Acid, 58.42, or 1 proportion, - - = 40
Lime, 41.58, or 1 " - - - -28
100.00 68

Crystallized sulphate of lime is composed of,
Sulphate of lime, 79.07, or 1 proportion, (anhydrous,) 68
Water, - 20.93, or 2 " - 18
100.00 86

4. Uses and miscellaneous remarks.

(*a.*) The native salt is abundant, in the form of alabaster, gypsum, or plaster stone, selenite crystals, &c. Found in the ashes of vegetables, in the sea, and in many natural waters; producing incrustations upon the pans of the salt boilers.*

There is a native variety without water, called the anhydrite, but it is rare, and its properties are different from those of the common kind.†

(*b.*) Heated, it loses weight .22, and if in a retort, water may be collected.

(*c.*) Exhibits a false appearance of boiling, in consequence of the escape of the water; this is best shewn in a glass retort, with the lamellated variety; it may be seen in a crucible with a forge heat.

(*d.*) Thus prepared for statuary and stucco work. Heat the plaster thoroughly, pulverize it fine, mix with a little good quick lime in fine powder, and form into a paste with water.

(*e.*) To copy a medal or coin, pour the paste into a box, oil the surface of the medal to prevent adhesion, and brush it over with the cream of the plaster to prevent air holes; then impress it upon the paste and let it harden.

(*f.*) To copy a face, living or dead, or a statue; the process is the same, only laying the figure on a table, oiling the surface, and if a living person, putting paper tubes in the nostrils, tying the hair back, and pouring on the plaster of the consistence of a thick cream. The muscles are kept composed, and in about 20 minutes, the cast will grow firm, when it is removed. After forming the concave copy, the convex is cast in it, and any mistakes are corrected or additions made; then a new concave is made upon this and serves as a permanent mould; statues are cast in parts and then joined. For stucco work, the plaster is cast in moulds, or figured on the spot to which it is applied.

---

* And in the boilers of the steam boats, that use salt water.

† It is found to be much more common than was formerly supposed.

(*g.*) Sometimes used to adulterate flour.

(*h.*) Discovered by weighing a given measure, by grittiness between the teeth, by alcohol throwing it down from water that has been boiled on the flour, by the tests for lime and sulphuric acid, by burning the flour in the open air, and examining the residuum and by forming heavy bread.

Besides the uses of this salt for statues, &c. it is employed in certain proportions with common lime plaster, to give it firmness and beauty, and such walls will bear washing and cleaning with soap. It is largely and most advantageously employed in agriculture as a manure, on sandy soils and grass lands.* It is extensively used in Switzerland, but very little, if at all, in Great Britain. It need not be burned, but merely pulverized. At Paris, and in Minorca, it is employed in building houses. Abundant in Nova Scotia, and in many of the Western American States; a very beautiful transparent variety is found at Lockport, and the compact variety exists extensively in other places in the state of New York.

SULPHATE OF BARYTA.

1. NAME, &c.

(*a.*) *The native mineral formerly called ponderous spar;* its sp. gr. being from 4.3 to 4.7.

(*b.*) Its composition first ascertained by Ghan.

2. NATURAL HISTORY.

(*a.*) *Found native,* in almost every country, particularly in metallic veins, of which it often forms the gangue; it is frequently amorphous, compact or granular, and of a pure white, or red, brown, yellow, &c.

(*b.*) *Often crystallized,* or fibrous, translucent, transparent or opake.†

3. PREPARATION.—*By mingling barytic water or any soluble salt of baryta, with sulphuric acid or any soluble salt containing it;* there is an immediate dense precipitate.

4. PROPERTIES.

(*a.*) *By heat, the foliated natural sulphate decrepitates,* and melts under the blowpipe, at about 35°, Wedg.

(*b.*) Tasteless and inodorous, insoluble in water; or requires according to Kirwan, 43,000 parts of water.

---

* The popular opinion that it will not answer near the sea, appears to be erroneous, as was proved by the late Mr. M. Rogers, at his place, near Stamford, Conn. where, as I heard him say, it produced the most striking effects on land washed by the salt water. Dr. Black says its effects last two years, and he asserts, contrary to our impressions in this country, that it is most efficacious on strong and rich lands.

† *Found sometimes in sandstone,* in Scotland; rarely, in the same country, in granite, in the place of the felspar; occasionally in the interior of Scotch agates, and in the ludus helmontii, of England.

(*c.*) *Soluble in concentrated sulphuric acid*, especially if boiling, but again precipitated by water.[*]

(*d.*) *Decomposed by ignition with charcoal;* its oxygen is separated in the form of carbonic acid, and sulphuret of barium is left.

(*e.*) Pulverized, kneaded up *with flour and water*, formed into a thin cake and *exposed to ignition, it becomes phosphorescent* in the dark.[†]

5. Composition.—Dr. Henry, after citing several analyses, concludes that the true composition is,

Acid,	33.90,	1 proportion, - -	40
Earth,	66.10,	" - - -	78
	100.00		118, its equivalent.

As baryta is used to separate sulphuric acid from all its combinations, *this salt is very important in analysis.* The quantity is determined by weighing the precipitate, previously washed and dried, and allowing 33.9 per cent. of its weight, " for real sulphuric acid," thus shewing the quantity in any sulphate.[‡] Sulphuric acid or any soluble sulphate occasions a sensible precipitate in a solution containing $\frac{1}{3000}$ of baryta, or of any of its soluble salts.[§]

6. Decomposition.—The mode by charcoal has been already mentioned.

(*a.*) *Not decomposed by any acid or alkali.*[‖]

(*b.*) *Readily by double elective attraction*, with carbonate of potassa, or of soda, or ammonia,[¶] *after long continued boiling.*

(*c.*) *But much more readily, by ignition with the carbonate of an alkali.*—Mix pure, decrepitated and pulverized sulphate of baryta, with twice its weight of dry, pure carbonate of fixed alkali, and expose them in a crucible to a violent heat. A double decomposition results, and carbonate of baryta and sulphate of alkali remain mixed in the crucible; wash out the soluble sulphate with water, dissolve the carbonate of baryta in muriatic acid; decompose it by the carbonate of an alkali, and thus, after strong ignition, especially in contact with charcoal powder, the pure earth will be obtained.

---

[*] Easily shown by adding sulphuric acid to solution of baryta, or any of its soluble salts; the precipitate will be redissolved by more sulphuric acid, and then thrown down by water, and thus it may be alternately redissolved and precipitated by acid and water.

[†] First observed, in the variety called Bologna stone, by an Italian shoemaker, named Vincenzo Casciarolo. This man found a Bologna stone at the foot of mount Paterno, and its brightness and gravity made him suspect that it contained silver. Having heated it to extract the silver, he observed that it was afterwards luminous in the dark, and on repeating the experiment, it constantly succeeded. It is evident that by the calcination, it must be converted, at least in part, into sulphuret. Prof. Olmsted informs me, that a granular sulphate of baryta from North Carolina, (Crowder's mountain,) when heated, phosphoresces with a clear white light.

[‡] Henry, 10th Ed. Vol. I, p. 604. [§] Thénard, III, 171.

[‖] Fourcroy asserts, (III, 82,) that the phosphoric and boracic acids, decompose it by ignition.

[¶] After boiling for two hours, about one fourth of it will be found to be decomposed, and the result will be carbonate of baryta, sulphate of the alkali, and undecomposed sulphate of baryta.

(*d.*) *Native carbonate* of baryta *dissolves in sulphuric acid, with a very slow* and scarcely perceptible *effervescence.*

7. Uses.

(*a.*) *To afford baryta* by its decomposition, and for the preparation of a phosphorescent substance.

(*b.*) It has been used *in the manufacture of porcelain*, particularly by the late Mr. Wedgwood.[*]

(*c.*) The artificial sulphate, *under the name of permanent white, is applied in painting* in water colors, and is the most delicate and permanent white known.[†] The carbonate is employed for the same purpose. Either of them may be used with advantage in labelling bottles in a laboratory, where acid vapors are so apt to destroy common writing ink.[‡]

(*d.*) *The sulphate of baryta is the only salt of this earth that is not poisonous.*—If the carbonate, which is a virulent poison, has been swallowed, diluted sulphuric acid would therefore be an antidote; and if any soluble salt of baryta has been taken, a solution of sulphate of soda or other alkaline or earthy sulphate would be the best remedy.[§]

SULPHATE OF STRONTIA.

1. Discovery.—*By Dr. Hope and Mr. Klaproth*, about the year 1793.

2. Natural History.

(*a.*) *Exists naturally in considerable abundance;* usually called celestine, from a delicate tinge of sky blue, which it frequently has; first observed at Strontian, in Scotland; found at Bristol, England; at Bouvron, France, and at Montmartre, near Paris; in splendid crystals in Sicily; also very beautiful at Put-in-Bay, Mackinaw, and Detroit, on the Great Lakes, and at Lockport, N. Y.

(*b.*) Found crystallized, massive, or in veins, "composed of needles, or very fine rhomboidal prisms;" sometimes foliated, fibrous, or granular; occasionally in sulphur beds.

---

[*] He employed it in what was called the jasper ware, which, for a long time, was made by Mr. Wedgwood alone; but the secret having been discovered and sold by a faithless servant, both the price and beauty of the vessels were soon much reduced by inferior artists.—*Parkes' Essays, Vol. I, p.* 317.

[†] Parkes.

[‡] Artificial sulphate mingled with lampblack, painter's oil and spirits of turpentine, for light colored bottles, drawers, &c. without the lampblack, for black bottles, &c.—C. U. S.

[§] Thénard, Vol. III, 172, says, "Le sulfate de baryte est employé en Angleterre comme mort-aux-rats." This appears to be a mistake; the carbonate is the substance actually used for this purpose.

(*c.*) Frequently confounded with sulphate of baryta, but easily distinguished from it, by its sp. gr. which is 3.85; it is always below 4. and sulphate of baryta always above 4.25

3. Preparation.

(*a.*) *By mingling sulphuric acid and strontian water*, when it is precipitated in the form of a white and tasteless powder.

(*b.*) *Or by mixing any soluble form of strontia, with any soluble sulphate.*

4. Properties.

(*a.*) *Tasteless and inodorous; nearly insoluble;* requiring 3000 or 4000 parts of cold, or 3840 of boiling water.

(*b.*) Dissolved in boiling sulphuric acid, and thrown down again by water; or in the additional mode named under sulphate of baryta, 4. (*c.*) note.

5. Composition.

Acid, 42+ earth 58=100.—*Wollaston.*
" 46+ " 54=100.—*Vauquelin.*
" 43+ " 57=100.—*Stromeyer.*

According to Dr. Thomson, it is composed of 1 proportion of strontia 52, and one of acid 40=92 for its equivalent, and this would require this salt to consist of 43.47 acid, and 56.53 base.

6. Decomposition.

(*a.*) *No acid decomposes it,*[*] nor does air affect it. At a high temperature it melts.

(*b.*) *No base except baryta can separate its acid;* but carbonates of the fixed alkalies decompose it with the aid of heat.

(*c.*) *Decomposed by ignition with charcoal*, in the same manner as sulphate of baryta is. It has not been applied to any use.[†]

SULPHATE OF MAGNESIA.

1. Name and Preparation.

(*a.*) That of the shops, called *Epsom Salts*, from a mineral spring at Epsom, in Surrey, (Eng.) where, mixed with some sulphate of soda, it was first obtained by Dr. Grew, A. D. 1675. But Dr. Black first distinguished it from Glauber's salt, with which it had, till his time, been confounded.

(*b*) *Formed, by dissolving* the carbonate of *magnesia*, or calcined magnesia, *in sulphuric acid*, somewhat diluted; it is then evaporated and crystallized.

(*c.*) *Strong sulphuric acid and calcined magnesia, produce great heat*, and sometimes light; but this acid evolves no heat with the carbonate, because the gas carries it away.

---

[*] The phosphoric and boracic effect its decomposition, if aided by a red heat.—Fourcroy, Vol. III, p. 48.

[†] Except in pyrotechny, for preparing the nitrate of strontia an ingredient of *red fire*.—J. T.

2. Properties.

(*a.*) *Crystals four sided prisms*, with quadrangular pyramids, having dihedral summits.*

The prismatic form, according to Mr. Brooke, is a right rhomboidal prism, of 90° 30, and 89° 30.

(*b.*) The Epsom salt of the shops is in the form of confused needle like crystals.

(*c.*) *When pure, unchanged in the air;* but sometimes deliquescent, from mixture with the muriate.

(*d.*) *Suffers aqueous fusion at low redness;* and loses about half its weight, but is not volatilized, except a little of the acid.

(*e.*) *Soluble at* 60°, *in* 1 *part of water*, in ¾ of its weight at 212°, the water is expanded ¼.

(*f.*) *Solution precipitated by carbonates of potassa and soda*, (see those articles.) Equal weights of the salts, in equal weights of boiling hot water; or, crystallized sulphate 4 parts, carbonate of potassa 3 parts, in solution; 100 grains dry sulphate give about 71 carbonate of magnesia, or 33. pure earth.

(*g.*) *The carbonate* is, in this case, preferable to the bi-carbonate of an alkali, because abundance of carbonic acid suspends the magnesia; heat would however, eventually throw down a precipitate.

(*h.*) *Carbonate of ammonia does not precipitate* the earth, unless heat is applied.

(*i.*) *Barytic, strontitic, and lime water throw down a mixed precipitate* of carbonate of magnesia and a sulphate of the other earth.

(*j.*) *Decomposed by charcoal at ignition;* producing a sulphuret, which is, however, feeble in its properties.

(*k.*) *At a high heat completely fusible*, but without decomposition.

(*l.*) *Taste bitter*, but less disgusting than that of sulphate of soda.

(*m.*) *An excellent cathartic;* dose, 6 or 8 drachms, dissolved in water; and, by many, preferred to Glauber's salts.

3. Composition.—1 proportion of	magnesia	20	33.04
1 "	sulphuric acid,	40	66.96
	its equivalent number,	60	100.00

The crystals contain,

Magnesia,	16.	or	1 propor.	20
Acid,	32.57	or	1 "	40
Water,	51.43	or	7 "	63
	100.00			123 the equivalent for the crystals.

---

* For some varieties of the crystals, see Henry, Vol. I, p. 621.

(*a.*) *With pure ammonia, a part of the earth is precipitated;* by evaporation a triple salt, called the ammoniaco-magnesian sulphate, is obtained, consisting of

Sulphate of magnesia,	1	proportion	60
Sulphate of ammonia,	1	"	57
Water,	7	"	63
			180 its equivalent number.

(*b.*) *A compound sulphate of magnesia and soda* is obtained, by evaporating the bittern of sea water; it crystallizes in transparent rhombs, and consists, according to Dr. Murray's analysis, of sulphate of magnesia 32, sulphate of soda 39, and water 29; and its proportions are very nearly those of 1 equivalent of sulphate of magnesia 60, 1 of sulphate of soda 72, and 6 of water, 54=186 for its equivalent number. It is a cathartic, not disagreeable to the taste, and is sold at Lymington, England.*

(*c.*) A sulphate of potassa and magnesia† is obtained, when 1 equivalent of sulphate of magnesia and 1 of sulphate of potassa are mixed; they crystallize with 6 of water, and there is a double salt of 1 equivalent of sulphate of magnesia, and 1 of sulphate of ammonia, with 8 of water, which is obtained by spontaneous evaporation of the mixed solutions.

4. ORIGIN OF SULPHATE OF MAGNESIA.

(*a.*) *Found abundantly in sea water*, and obtained from the bittern, after the evaporation for crystallizing common salt; it is boiled down, until, on cooling, in clear and cold weather, it affords the sulphate of magnesia, in acicular crystals, in the proportion of 4 or 5 parts to 100 of common salt, obtained from the same water; or sulphate of iron is added, to decompose the muriate of magnesia, and thus increase the quantity of sulphate.‡

(*b.*) *Manufactured from magnesian minerals*, especially the magnesite; 1.500,000 lbs. are made annually in Baltimore, from a magnesite found near Chester, Penn.§

(*c.*) *Found native and crystallized*, in remarkable quantity, in a great cave, at Corydon, Indiana; also in many other limestone caverns, in Kentucky, Virginia, and Tennessee, &c.

(*d.*) Effloresces occasionally on brick walls.

(*e.*) *Formed by the decomposition of rocks*, which contain magnesia, and sulphuret of iron; the latter affords the sulphuric acid, which combines with the magnesia, and effloresces, and is extracted by a process, for which see Thénard, 5th Ed. Vol. III, p. 169.

---

* Murray, 6th Ed. Vol. II, p. 94, and Edinburgh Trans.

† See Phil. Trans. 1822, p. 455, also Henry, 10th Ed. Vol. I. p. 625.

‡ See muriate of magnesia.

§ Am. Jour. Vol. XIV, p. 10. See also Vol. IV, p. 22.

(*f*.) *Also by calcining the magnesian limestones;* treating them with muriatic acid to dissolve the lime, and then with sulphuric acid, or sulphate of iron, to form the sulphate of magnesia.*

SULPHATE OF ALUMINA AND ALUM.

Common alum.

1. Preparation.—*Always prepared in the large way; rarely by the chemist, unless in analysis.*

2. Properties.

(*a*.) Its properties are always shown by the alum of commerce, which is a triple salt, and not mere sulphate of alumina, which has characters entirely different.

(*b*.) *Crystals formed from a hot concentrated solution, filtered;* a frame of sticks or some hairs or strings or wires are often suspended in it, for the crystals to adhere to; they form a beautiful group, and are handsomely exhibited in a bottle.

(*c*.) *Aqueous fusion and subsequent desiccation by heat,* on an ignited iron; the product was formerly called *alumen ustum;* there is a partial expulsion of the acid—so that the solution of the desiccated alum does not easily redden blue vegetable colors.† By a very violent heat, most of the acid is expelled. The solution of the crystals reddens litmus liquor decidedly, cabbage liquor slightly, "*but blue tinctures,* from the petals of plants, are generally turned by it green."‡

(*d*.) *Air has generally no action*—sometimes produces a slight efflorescence.

(*e*.) *Taste, sweetish, acid, and astringent; rather agreeable to most persons.*—Specific gravity 1.71.

(*f*.) *Water* 5 *parts at* 60° *dissolves* 1 of the salt; at 212° 1 part of water dissolves three fourths of its weight.

(*g*.) *Pyrophorus.*—Take 3 parts of alum and 1 of flour or brown sugar, heat the mixture, and stir it constantly, in an iron pot or ladle, till it has ceased to swell, and has become dry; powder the mixture finely, and introduce it into a vial coated with clay; set this in a sand heat, and continue the heat till gas ceases to be inflamed, by bringing a lighted paper to the mouth; we are usually directed to introduce a small tube, through a perforated cork, into the vial's mouth; when the operation is over this may be removed and a cork substituted.

(*h*.) *This pyrophorus fires in the air; more vividly, in a jar of oxygen gas;* it fires also in chlorine and nitric oxide gas.

---

* Id. and Ann. de Chim. et de Phys. T. VI, p. 86, and Gray's Op. Chem.

† It is suggested that the effect of alum on blue colors, may be owing to a feeble affinity between the acid and the earth, and of course to an attraction between the acid and the coloring matter, rather than to an excess of acid.

‡ Quarterly Jour. XVIII, 396.

The foregoing process for pyrophorus, which is the usual one, is of rather uncertain success, and the theoretical reasoning formerly given respecting it being imperfect, I do not repeat it here; but proceed to state a better process, furnished me by Dr. Hare, and one which rarely fails to succeed.

Take lampblack 3 *parts, calcined alum* 4, *pearl ashes* 8, *mix them thoroughly, and heat them for one hour*, in a coated iron tube, to a bright cherry red, or full red, but not to a white heat. Black's furnace, filled with charcoal thoroughly ignited, the flues being then shut, and when the fuel is half burnt down, again filled, and allowed to burn quietly out, with the flues still cloesd, or nearly so, will give a good pyrophorus. The tube must not be opened until it is cold, and then very cautiously. The pyrophorus may be jarred out, by inclining the tube, and gently striking it with a hammer. If good, it fires on falling out, especially if the air is damp, or if breathed upon; caution should be observed lest the little explosions injure the eyes. If a ramrod be introduced to detach the pyrophorus, the operator should be on his guard, as a violent explosion sometimes happens, discharging the whole contents at once, with a loud report.* This pyrophorus fires brilliantly, if a large stream of oxygen gas be directed upon it from a gazometer, or if it be poured into oxygen, or chlorine or nitric oxide gas. It fires also, if thrown upon water or fuming nitrous acid. There can be little doubt that sulphuret of potassium must be formed in this process, and that to potassium, in some state or other, the principal phenomena must be attributed.

(*i.*) *All the alkalies and soluble alkaline earths decompose this salt*, and if ammonia enter into its constitution, it is perceived by the odor, when either of the other alkaline bodies is added and heat applied, and by the cloud formed with the fuming acids.

(*j.*) *All the alkalies throw down the alumina;* potassa and soda redissolve it, if added in excess, and yield it up again if detached by an acid.

(*k.*) *Ammonia precipitates the earth without redissolving it*, or only very slightly, and heat would throw down even this little.

(*l.*) *The soluble alkaline earths throw down a mixed precipitate*, of alumina and the earths, combined with the sulphuric acid.

(*m.*) Baryta and strontia, are proper for the discovery of potassa; if present, it would remain in solution, and could be detected by muriate of platinum.

(*n.*) *The carbonates of alkalies decompose this salt*, with a slight effervescence at first, and throw down a carbonated earth.

(*o.*) *Crystals of alum are usually octahedral;*

---

* See Am. Jour. of Science, Vol. X, p. 366, and the same thing has often occurred to me since.

(*p.*) *But they become cubical*, by letting a solution of common alum stand for some time upon either alumina or potassa; still, with a great excess of potassa, alum does not crystallize.

(*q.*) *Saturate alum, with alumina*, by boiling a solution of common alum upon it; *it becomes a tasteless insoluble powder*.

(*r.*) *Digest natural clays in sulphuric acid;* they dissolve only partially, and scarcely saturate the acid; dissolve newly prepared alumina (added in excess) in sulphuric acid, and a neutral sulphate is formed, which crystallizes in thin flakes, and becomes alum by adding potassa or its sulphate.

2. COMPOSITION AND VARIETIES.

(*a.*) The most common variety of alum is that which contains potassa, but there has been considerable diversity in the statements made of its constitution: the following is the average of six analyses.[*] Sulphuric acid, 33.22; aluminous earth, 11.07; potassa, 9.88; water, 45.92=100.

(*b.*) According to Mr. R. Phillips, alum consists of 1 proportion of bi-sulphate of potassa, 128; 2 of sulphate of alumina, (67×2) =134; 25 of water, (9×25) =225=487,[†] its equivalent number.

Dr. Thomson supposes alum to be composed of 1 proportion of sulphate of potassa, 88; 3 of sulphate of alumina,[‡] (58×3) 174; 25 of water, 225=487.

The difference between these two views is, that in the former the equivalent of alumina is taken at 27, and in the latter at 18; and adding 40 in each case for the sulphuric acid, we have 67 and 58 for the equivalent of sulphate of alumina, of which 2 proportions are taken in Mr. Phillips' statement, and 2 in that of Dr. Thomson.

(*c.*) *Alum with basis of ammonia*,[§] consists of 1 proportion of sulphate of ammonia, 57; 3 of sulphate of alumina, 58×3=174; 24 of water, 9×24=216; and of the acid, 26.979 are united to 11.906 of the earth, and 9.063 are united to 3.898 of ammonia.

(*d.*) *Alum with basis of soda.*[‖]—Its composition is stated as being water, 51.21; acid, 32.14; earth, 10.; soda, 6.32: or, 2 proportions of sulphate of alumina, 1 of bi-sulphate of soda, 28 of water. A native soda alum is found in the isle of Milo, Greece, and in South America.[¶]

---

[*] As given by Dr. Henry, Vol. I, p. 632, 10th ed.

[†] In this statement, the experimental results are slightly changed, to accommodate them to definite proportions, and the equivalent of alumina is taken at 27.

[‡] The equivalent of alumina being taken at 18. The chemical equivalent of alumina is not yet ascertained with certainty, but Mr. Murray remarks, (II. 182,) that from the analysis of salts and minerals containing alumina, it is more probable that 18 is the true number.

[§] According to Riffault, Ann. de Chim. et de Phys. IX, 106.

[‖] Quarterly Jour. VIII. 386, and XIII. 276. I have prepared a lithia alum, in large quantities, from the Sterling spodumene, in following Berzelius' process for extracting lithia. It is deliquescent, but in other respects resembles the potassa alum.—J. T.

[¶] Am. Jour. Vol. XVI. p. 203.

(*e.*) Magnesia also appears to form a variety of alum, but it has not been applied to use.

(*f.*) For a notice of *a neutral sulphate of alumina*, and for one of a sub-sulphate of alumina and potassa, &c. see Henry, Vol. I, p. 634, 10th ed.—Ann. de Chim. et de Phys. VI, 201 and XVI, 355, and Dr. Thomson's First Principles, I, 313.

SULPHITES OF ALKALIES AND EARTHS.

General characters.

1. Taste and smell like that of burning sulphur.
2. Heat expels sulphurous acid and water, and finally sulphur, which, when inflamed, burns violently, and a sulphate remains.*
3. Solution slowly absorbs oxygen from the air and becomes sulphate.
4. Chlorine and nitric acids convert the sulphites into sulphates; and nitric acid gives out red fumes. Sulphuric and muriatic acids expel the sulphurous acid with effervescence.
5. The sulphites are not precipitated by solution of baryta or strontia, or by any of their salts.
6. They are formed by passing a stream of sulphurous acid gas through the base, dissolved or suspended in water.
7. The alkaline sulphites are most soluble and crystallizable.
8. A neutral sulphite, when its acid is oxygenized, always forms a neutral sulphate.

SULPHITE OF LIME.

1. Besides the general method, already mentioned, this salt may be formed from the carbonate.
2. Insoluble at first, but is dissolved by continuing to pass sulphurous acid through it.
3. Crystallizes in six sided prisms, acuminated by six planes.
4. Requires 800 parts of water for solution, unless there be an excess of acid.
5. Proportions, lime 28, sulphurous acid 32, by theory.—*Brande.*

SULPHITE OF BARYTA.

1. It may be formed by passing sulphurous acid over carbonate of baryta.
2. A white powder, little soluble, becomes more so by passing sulphurous acid gas in excess through the powder.
3. *Composition.*—Baryta 78, acid 40; by theory, one proportion of each.

---

* Except the sulphate of ammonia, which is entirely exhaled.

SULPHITE OF STRONTIA.

This salt is most easily formed, by mingling an alkaline sulphite with a solution of the earth in an acid, when there will be a precipitate of the sulphite of strontia, which is insoluble.

SULPHITE OF MAGNESIA.

1. Formed also by diffusing the carbonate in water, and passing sulphurous acid gas through it.
2. Insoluble till there is an excess of the acid; gives crystals which are flattened tetrahedra.
3. Requires 20 parts of cold water for solution.
4. Taste sweetish and earthy.

SULPHITE OF ALUMINA.

1. A white soft insoluble powder.
2. Soluble in an excess of acid.

SULPHITE OF POTASSA.

1. Formed with ease, from a saturated solution of the carbonate.
2. Crystals, long rhomboidal plates or divergent needles.
3. Soluble in water, 1 part at 60°, in less at 212°.
4. Composition, 43.5 acid, 54.5 potassa, 2 water; (*Thomson*) by theory, 1 potassa, 48; 1 acid, 32=80, its equivalent.
5. Slightly effloresces in air, and becomes sulphate; decrepitates.
6. Decomposed by baryta and lime.

SULPHITE OF SODA.

1. Crystals, tetrahedral prisms, with dihedral summits.
2. Dissolves in 4 parts of cold water, in less than 1 at 212°.
3. Effloresces; suffers aqueous fusion, and is decomposed at last by heat.
4. Composition, soda 1 proportion 32, acid 32, water 9=108; =172 for the equivalent.
5. Potash decomposes it, attracting its base.

SULPHITE OF AMMONIA.

1. Crystals, six sided prisms, terminated by pyramids with the same number of sides, or rhomboidal prisms with trihedral summits.
2. Soluble in 1 part of cold water, and in less at 212°.
3. Deliquesces, and becomes converted into a dry sulphate.
4. Fused and volatilized by heat.
5. Composition, 17 ammonia, 32 acid, for the anhydrous salt, giving 49 for its equivalent; and when crystallized, 2 equivalents of the salt,=98+1 of water, 9=107 by theory.—*Brande.*

HYPO-SULPHUROUS ACID. HYPO-SULPHURIC ACID.
HYPO-SULPHITES. HYPO-SULPHATES.

Remarks.—In the present advanced state of chemistry, the most serious inconvenience encountered by the student, is found in the great extent and variety of details. In a concise elementary work, it is impossible to present them all, and there seems to be no better course than to omit, or to notice slightly the least important, and to enlarge upon those of the opposite character, giving at the same time, sufficient references to original sources of information.

Were it not that it is desirable to preserve the chemical history of bodies unbroken, and particularly to display the extent and precision of definite and multiple proportions, I should hardly have thought it best to say any thing of the preceding sulphites or of the acids and their compounds which stand at the head of these remarks.

HYPO-SULPHUROUS ACID.

1. *Composition.*—1 proportion of oxygen, 8, and 1 of sulphur, 32 =40, for its equivalent.

2. *Preparation.*—Difficult to obtain and preserve in an isolated state. It is done,

(*a.*) By decomposing the dilute solution of hypo-sulphite of strontia, by dilute sulphuric acid; the earth is precipitated and the acid liberated.

(*b.*) By digesting sulphur in a solution of any sulphite, when an additional proportion of sulphur is dissolved, and hypo-sulphurous acid formed; or by decomposing hydro-sulphuret of lime* or strontia, by a stream of sulphurous acid gas, when there is an exchange of one proportion of the oxygen of the sulphurous acid for one proportion of the sulphur of the hydro-sulphuret, water being formed, and thus two proportions of sulphur remain in union with one of oxygen.

3. *Properties.*—A transparent, colorless, inodorous acid; decomposed spontaneously, sulphur precipitated, and sulphurous acid remains.

HYPO-SULPHITES, OR SULPHURETTED SULPHITES.

1. *Preparation.*

(*a.*) The hypo-sulphites of the alkalies and alkaline earths are best obtained by passing a stream of sulphurous acid gas through a lixivium of those bodies that has been boiled with sulphur; the sulphurous acid is converted into hypo-sulphurous, and the excess of sulphur precipitated.

(*b.*) By boiling a sulphite with sulphur.

(*c.*) By double decomposition; an alkaline hypo-sulphite being mixed with an acid solution of some other base.

---

* See p. 347.

2. *Properties.*

(*a.*) Generally soluble in water, and have a bitter taste; precipitate nitrate of silver and mercury black, in the form of sulphurets of those metals; salts of lead and baryta are thrown down as white insoluble hypo-sulphites of those bases.

(*b.*) Muriate of silver, recently precipitated, is dissolved by the hypo-sulphites, and especially by that of soda, and a fluid is formed sweeter than honey, and entirely void of metallic taste. The hypo-sulphite of ammonia forms with muriate of silver, a white salt of which 1 grain imparts a perceptible sweetness to 32,000 grains of water.*

HYPO-SULPHURIC ACID.

1. *Discovery.*—In 1819, by Welter and Gay-Lussac.†

2. *Preparation.*—Black oxide of manganese in fine powder, is suspended in water, and a stream of sulphurous acid gas passed through; two acids are formed by the oxygen of the manganese; the sulphuric and hypo-sulphuric, and both unite with the base, forming sulphate and hypo-sulphate of manganese; both are decomposed by adding solution of baryta slightly in excess, which precipitates manganese and sulphate of baryta, and leaves hypo-sulphate of baryta in solution. Carbonic acid gas is then passed through, to remove any excess of baryta; the solution is boiled to expel the carbonic acid, and by evaporation, hypo-sulphate of baryta is obtained in crystals. To a solution of these crystals, sufficient sulphuric acid is cautiously added to saturate the baryta, which is precipitated in the form of sulphate, and the hypo-sulphurous acid remains in solution.

3. *Properties.*

(*a.*) A colorless, inodorous acid, changes the test fluids; concentrated by heat, or under the receiver of the air pump, its sp. gr. is 1.347, but if attempted to be carried farther, especially by heat, it is decomposed and converted into sulphurous and sulphuric acids.

(*b.*) Suffers no change from the air or from nitric acid; it dissolves zinc like the stronger acids, and forms hypo-sulphate of zinc, while hydrogen gas is evolved.

(*c.*) It forms soluble salts with baryta, strontia, lime, lead, and silver, which completely distinguishes it from sulphuric acid.

4. *Composition.*—Ascertained by decomposing the hypo-sulphate of baryta by heat, and the proportion of sulphur appears to be 1=32, and of oxygen, 5=40=72, for its equivalent.

HYPO-SULPHATES.

1. *Preparation.*—Formed by direct combination with bases.

---

* For numerous additional particulars, see Ann. de Chim. Vol. LXXXV; Edin. Philos. Jour. Jan. 1819, Vol. I, 8, and 396, and Ure's Dict. 2d Ed. p. 97.

† Ann. de Chim. et de Phys. Vol. X.

2. *Properties.*

(*a.*) All soluble; decomposed by a moderate heat, sulphurous acid gas being exhaled and sulphates remaining.

(*b.*) Strong sulphuric acid decomposes the acid of the hypo-sulphates, at the instant when it is decomposing the salts which contain it; a weak acid, applied cold, separates the hypo-sulphuric acid without decomposition.

(*c.*) Not changed by the air, or only slightly absorb oxygen.

The hypo-sulphate of baryta crystallizes in square prisms of peculiar brilliancy; that of potassa in a cylindroidal form; that of lime in hexagonal, and that of strontia in very small hexahedral laminæ.

Composition of the acids of sulphur.

	Sulphur.		Oxygen.	
Hypo-sulphurous acid, - -	16	+	8	1 and 1 propor.
Sulphurous acid, - - -	16	+	16	1 and 2 "
Sulphuric acid, - - -	16	+	24	1 and 3 "
Hypo-sulphuric acid, - -	32	+	40	2 and 5 "

Thus these compounds beautifully illustrate the laws of definite and multiple proportions.

COMPOUNDS FORMED BETWEEN SULPHUR, HYDROGEN, AND THE ALKALIES AND EARTHS.

SULPHURETTED HYDROGEN.

1. Nomenclature.—The termination *uret* is appropriated to combinations of simple combustible, non-metallic* bodies, with each other and with the metals, alkalies, and earths. Thus, in the case of sulphur and phosphorus, we have sulphuret of phosphorus, or phosphuret of sulphur, sulphuret or phosphuret of lime, and of calcium, of potassa, and of potassium, of iron, &c. To denote different proportions of the principles, terms are derived either from some sensible property, usually the color; e. g. we have a black and red sulphuret of mercury, yellow and red sulphuret of arsenic, &c.; or it is now more usual to prefix the same terms that are applied to the oxides, as proto-sulphuret, deuto-sulphuret, &c. implying one or two proportions of sulphur, &c.

Where the compound is gaseous, it is usual to add *ted* to the termination *uret;* as sulphuretted hydrogen and phosphuretted hydrogen, instead of sulphuret and phosphuret of hydrogen.

2. History.—Known to Rouelle, but first investigated by Scheele, A. D. 1777; afterwards by many distinguished chemists.

3. Processes.

(*a.*) *By heating sulphur in hydrogen gas*, by the solar rays; or by subliming sulphur, repeatedly, in hydrogen gas; or, by passing this gas over sulphur heated in a porcelain or coated glass tube.

---

* The compounds of metallic bodies with each other are called alloys.

(*b.*) *Better by the aid of sulphuret of iron*, to prepare which, mingle flowers of sulphur and iron filings, equal parts;[*] heat them in an iron pot or skillet, under a chimney, not merely till the sulphur melts, which happens almost immediately, but until an intimate chemical union is indicated, by incandescence pervading the entire mass; it begins with a little luminous spot or spots, and gradually extends through the whole, while the vessel containing the materials is perhaps not even red; at this moment, the boiling and combustion of sulphur cease, for it is now detained by its affinity for the iron. The sulphuret being pulverized, is fit for use, and will not disappoint the experimenter.[†]

(*c.*) To one part of the sulphuret of iron thus made, add 2 of muriatic acid, with 4 of warm water, and when the gas begins to come languidly, a little heat may be applied.

(*d.*) Powdered sulphuret of antimony, with 5 or 6 times its weight of muriatic acid, (sp. gr. about 1.160,) apply the heat of a lamp; this process, although strongly recommended, has not succeeded well with me.

(*e.*) Add diluted sulphuric or muriatic acid to almost any alkaline sulphuret, preferably of potassa, but the gas comes too rapidly to be easily managed; process (*c.*) is the best.

4. PROPERTIES.

(*a.*) *Sp. gr.* 1.18, air being 1; 100 cub. inch. weigh nearly 36 grains.[‡]

(*b.*) *Smell very offensive*, like that of rotten eggs, or of sulphureous mineral waters.

(*c.*) *When kindled in contact with air, it burns quietly*, with a bluish white flame, and deposits sulphur on the glass vessel.

(*d.*) *Mixed with common air, it burns* more rapidly.

(*e.*) *With oxygen*, three measures to two of this gas, *it detonates*, producing water and sulphurous acid.

(*f.*) *Water absorbs its own volume* or, if the gas be pure, even two or three times its volume, and then resembles exactly, the native sulphureous waters.

---

[*] Or sulphur 1 part, iron 2.

[†] The mere melting of iron filings and sulphur, and still more the mere mingling of them will not answer; for, when the acid is added, the gas produced will be merely a mixture of sulphuretted hydrogen, and common hydrogen gas. The process by rubbing roll sulphur upon a bar of iron heated to whiteness, till liquid drops fall, gives also a true sulphuret which will afford the gas, but the manipulation is more troublesome, and the product of sulphuret of iron is small.

The following process was communicated.—Heating the native yellow pyrites, in a close crucible, till 1 proportion of sulphur is expelled; and a fine proto-sulphuret will be left. J. T.

[‡] 35.89, according to Dr. Thomson. Different authors have stated its sp. gr. differently.

(*g.*) *This fluid tarnishes metallic solutions*, and bright metals; e. g. silver, mercury; also, white paint, acetate of lead, muriate of bismuth, nitrate of silver, &c.

(*h.*) *Write with a solution of silver or lead* on cards, and expose them to this gas; Dr. Henry found that $\frac{1}{20000}$ part of this gas, mixed with common air, or hydrogen, or carburetted hydrogen, produced a sensible discoloration of white lead, or of oxide of bismuth, mixed with water and spread upon a card.

(*i.*) *Moisten the entire surface of cards with the solution*, and expose them as above, when they will be entirely tarnished.

(*j.*) *Aqueous solution reddens* infusion of *violets or litmus* liquor or paper, and in this respect resembles the acids.

(*k.*) *Sulphuretted hydrogen being mixed with sulphurous acid*, either liquid or gaseous, *sulphur is deposited* by mutual decomposition; if 3 volumes of sulphuretted hydrogen be mixed with 2 of sulphurous acid gas, both being dry, they are entirely condensed into an orange yellow substance, having acid properties, and consisting, according to Dr. Thomson, of 5 proportions of sulphur, 4 of oxygen, and 3 of hydrogen.*

(*l.*) *Liquid sulphuretted hydrogen deposits sulphur*, by exposure to air, or even in a bottle, and in the channels where the sulphureous mineral waters run. Fuming nitrous acid precipitates the sulphur, but the colorless acid does not.

(*m.*) *Fuming nitrous acid*, being poured into a wide mouthed receiver, filled with sulphuretted hydrogen, *decomposition happens*, and a beautiful flame spreads through the interior of the vessel.†

(*n.*) *Chlorine decomposes this gas and precipitates the sulphur.*

(*o.*) *Very hostile to life*; if pure, kills almost instantly; or even if mingled with a large proportion of air, it is very noxious. Air containing only $\frac{1}{1500}$ killed a bird, $\frac{1}{800}$ a dog, and $\frac{1}{250}$ a horse.‡ A young rabbit, whose head was in the pure air, and its body enclosed in a bladder filled with sulphuretted hydrogen, died in 15 or 20 minutes; old rabbits lived longer. It is fatal, therefore, when applied to the surface of the body.

(*p.*) *Sulphuretted hydrogen precipitates all the metals*, except iron, nickel, cobalt, manganese, titanium, and molybdena.

(*q.*) *Electricity and galvanism throw down sulphur*, and an equal volume of hydrogen gas remains; sulphuretted hydrogen is partially decomposed, by being passed through an ignited porcelain tube, or over ignited charcoal.—*Thénard.*

---

* Ann. Phil. Vol. XII, p. 441.

A similar decomposition is supposed by Prof. Daubeny to be the principal source of volcanic sulphur. See his lectures on Volcanos, Am. Jour. Vol. XIII, No. 2.

† Ann. of Phil. Vol. VIII, p. 226, and Henry, Vol. I, p. 449, 10th Ed.

‡ Thénard, Vol. I, 728.

(*r.*) Alkalies absorb it readily, and thus it is easily separated from common hydrogen.

(*s.*) *Potassium and sodium, heated in this gas burn brilliantly;* i. e. much heat and light are evolved, and a sulphuret of the metal is formed, while as much hydrogen gas is produced as the metal would have liberated from water. Diluted muriatic acid produces from the sulphuret the original quantity of sulphuretted hydrogen gas.

5. COMPOSITION.—According to Dr. Thomson, it is composed of 1 volume of the vapor of sulphur =1 proportion 1.111, +1 vol. of hydrogen gas, 0.069; these numbers being almost exactly in the ratio of 1 : 16, give the equivalent weight of sulphur very nearly the same as that deduced from the composition of sulphuric acid.*

6. LIQUEFACTION OF SULPHURETTED HYDROGEN.

(*a.*) Mr. Faraday, by disengaging this gas in a recurved tube, sealed, before the materials were brought into contact, the end opposite to that in which they were contained being kept cold by a freezing mixture, succeeded in condensing it into a liquid.

(*b.*) It was limpid, colorless, and more fluid than ether; equally fluid at 0 as at 45° Fahr. and its refractive power greater than that of water.

(*c.*) The tube being opened under water, the fluid rushed instantly into gas, which was sulphuretted hydrogen. The pressure of its vapor, at 50° of Fahr.† was equal to seventeen atmospheres, or 255 lb. to the square inch.

Remarks.—Sulphuretted hydrogen gas exists abundantly in the sewers and privies of great cities. I have observed, in London, that a sudden and heavy rain would force it out in great quantities, tainting the atmosphere, and tarnished white lead paint. In great cities, especially in Paris, it is often fatal to those who clear away the filth of the sewers: the best antidote and remedy is chlorine, especially in the form of chloride of lime.

BI-SULPHURETTED HYDROGEN.

1. DISCOVERY.—By Scheele originally, and afterwards examined by Berthollet.‡

2. PREPARATION.—Boil flowers of sulphur with liquid potassa; pour this reddish brown solution, by little and little, into muriatic acid; very little sulphuretted hydrogen escapes, and a part of it combines with more sulphur, and precipitates, of an oily appearance; or, fill one third of a vial with muriatic acid, of the sp. gr. 1.07, and pour

---

* Henry, Vol. I. p. 446, 10th Ed.

† Phil. Trans. 1823, p. 192.

‡ Ann. de Chim. XXV, and Phil. Trans.

in an equal bulk of the above named compound of sulphur and alkali; the vial being corked and shaken, the peculiar fluid gradually subsides to the bottom, in the form of "a brown, viscid, semi-fluid mass."—*Henry*. The hydrogenized sulphuret of lime is also used, in the same manner, for obtaining this compound.

3. Properties.

(*a.*) Odor like that of putrid eggs; heavier than water; burns with the smell of sulphurous acid.

(*b.*) A gentle heat causes sulphuretted hydrogen to exhale, and sulphur only is left.

(*c.*) It unites with alkalies and earths, and produces the sulphuretted hydro-sulphurets, or hydroguretted sulphurets.

(*d.*) If kept in a vial, floating on water, it exhales sulphuretted hydrogen, whenever the stopper is withdrawn.

(*e.*) If placed on the tongue, it gives a pungent bitter taste, exhales sulphuretted hydrogen, and leaves sulphur in the mouth.

4. Composition.—According to Mr. Dalton, 2 proportions of sulphur $=32+1$ of hydrogen $=33$. In centesimal proportions,[*] it consists of sulphur 96.75, hydrogen $3.25=100$. Its combinations with alkalies will presently be considered.

HYDRO-SULPHURETS.[†]

COMPOUNDS OF SULPHURETTED HYDROGEN AND BASES.

Introductory Remarks.

It has been already observed, that sulphuretted hydrogen performs the functions of an acid. It is not sour to the taste, but it reddens the infusion of vegetable blue colors, or at least that of litmus or radishes; its most important character, as an acid, is, that it combines with the alkalies and alkaline earths, neutralizing their alkaline properties, and forming crystallizable compounds, analogous to the salts. Some have therefore enrolled sulphuretted hydrogen among the acids, but, in a free state, except a feeble effect upon some of the blue test colors, its properties are so different from those of acids, that I prefer to consider it as merely a compound combustible gas, adding a notice of those properties that assimilate it to acids.[‡]

1. Preparation *of hydro sulphurets.—Formed, by passing sulphuretted hydrogen gas through the base,* suspended or dissolved in water, in Woulfe's or other convenient apparatus.

---

[*] Henry, Vol. I, p. 447.

[†] Called by some authors hydro-sulphates, but it would seem, unhappily; as the learner is in danger of confounding them with the sulphates: the old name appears to be unexceptionable. See Dr. Turner's Chemistry, 2d ed. p. 603.

[‡] It has been called the hydro-thionic, and the hydro-sulphuric acid; neither name has obtained much currency, and the latter confounds this body with the common sulphuric acid.

2. **General properties.**

(*a.*) *Soluble in water*, recent solution colorless, by exposure to the air become greenish or yellowish, and deposit sulphur on the sides of the vessel.

(*b.*) If the bottle in which they are kept contains lead, it is reduced, and coats the interior with a metallic lining, probably a sulphuret.

(*c.*) By long exposure to the air, and even by long keeping, they pass to the state of sulphites, and ultimately to that of sulphates, which are sometimes precipitated, and sometimes remain, in part or in whole, in solution.

(*d.*) *Acids liberate sulphuretted hydrogen, but do not precipitate sulphur;*

(*e.*) Except* the nitric acid, which combines with the hydrogen to form water, and thus liberate sulphur;

(*f.*) Except also when the hydro-sulphurets have been partially decomposed by careless keeping, when they throw down sulphur.

(*g.*) *Precipitate all metallic solutions*, and also alumina and zirconia, but no other earths.

(*h.*) Generally crystallizable.

(*i.*) Take up an additional dose of sulphur, by digestion, upon it, but do not suffer it to be again precipitated by a stream of sulphuretted hydrogen.

(*j.*) After exposure, for some time, to the air, exhale sulphurous acid gas along with sulphuretted hydrogen, and precipitate sulphur.

(*k.*) Absorb oxygen, and therefore used in eudiometry.

(*l.*) If there is no more sulphuretted hydrogen than is necessary to saturate the base, they are inodorous; but they usually have the odor of sulphuretted hydrogen, because it not only saturates the base, but combines with the water of the solution, which after the superfluous gas is expelled, by heat, will no longer have any odor.

(*m.*) The hydro-sulphurets are decomposed by heat, and the base remains; ammonia excepted, which is exhaled.

(*n.*) It is said that sulphuretted hydrogen combines with alkalies, in a double proportion, forming bi-hydro-sulphurets.

HYDRO-SULPHURET OF POTASSA.

1. Crystallizes in large transparent crystals, similar to those of sulphate of soda; four sided prisms acuminated by four planes, or six sided prisms with six planes, at the ends.

2. Taste alkaline and bitter, inodorous when dry, but becomes odorant by moisture; is deliquescent.

3. Forms a syrupy liquor, which imparts a green color to bodies in contact with it.

4. Dissolves, not only in water but in alcohol, producing cold.

---

* Chlorine produces the same effect by seizing the hydrogen.

HYDRO-SULPHURET OF SODA.

Crystals formed with more difficulty than the preceding; transparent, quadrilateral prisms, acuminated by four planes, bearing a close resemblance to the hydro-sulphuret of potassa.*

HYDRO-SULPHURET OF AMMONIA.

1. The two gases mixed over mercury, or in a bottle, or otherwise, combine; in equal volumes, they are almost completely condensed into an odorous cloud, which forms a soft white crystalline deposit on the inside of the vessel, and if it is kept cold by *ice*, acicular crystals will be formed.

2. The liquid solution is easily formed, but does not crystallize.

3. It is an excellent test, in examining metallic solutions.

4. Admitted into the Pharmacopæia, as a depressing and nauseating remedy, in cases of too great action—introduced by Dr. Rollo, and used chiefly in diabetes;† dose, 5 or six drops, three or four times a day, gradually increased, and mitigated, when nausea and giddiness supervene.

HYDRO-SULPHURET OF LIME.

1. Formed, by passing the gas, either through lime water, or milk of lime.

2. It is formed when sulphur is boiled with lime and water; but there is also another product soon to be described.

3. I have often seen distinct prisms formed in the solution made by boiling lime and sulphur to saturation in water; I am not aware that they have been examined; if not hydro-sulphuret, may they not be hypo-sulphite of lime?

HYDRO-SULPHURET OF BARYTA.

1. Formed, as mentioned in the general characters; but by far the best method is to obtain it from the decomposed sulphate, by charcoal, as described under sulphate of baryta, and soon to be mentioned again, with particular reference to this subject.

2. It crystallizes, confusedly, in brilliant plates, which must be dried between folds of blotting paper, and if immediately dissolved in distilled water, they form a colorless solution.

---

* It was formerly said to be distinguished, by not forming alum when added to sulphate of alumina, which the other salt would do, but this distinction was indicated, probably, before it was known that there is a triple soda alum.

† The physician can prepare this remedy by extricating the gas, under a chimney, in the manner already described under sulphuretted hydrogen, and passing it from an oil flask, or bottle, through the aqua ammoniæ of the shops, contained in a vial immersed in cold water, or better, surrounded by ice. This remedy has still considerable reputation, and conjoined with a diet of animal muscle, is thought to have produced the most salutary results. I have repeatedly prepared it for physicians, and have always heard a favorable report of its effects, *if conjoined with a rigorous diet.*

HYDRO-SULPHURET OF STRONTIA.

In every respect as the last, only the decomposition of the sulphate is not so striking.

HYDRO-SULPHURET OF MAGNESIA.

1. Formed by passing the gas through the magnesia suspended in water.

2. It is a feeble and imperfectly characterized compound.

SULPHURETTED HYDRO-SULPHURETS.*

General Characters.

1. Formed, by boiling flowers of sulphur with the base, dissolved or suspended in water.

1. Caustic heavy fluids, of a greenish yellow, or brownish color.

2. Stain the cuticle black, have an acrid taste, and an offensive smell.

3. *Deposit sulphur when kept in close vessels*, and become more transparent, and lighter colored.

4. *Absorb oxygen gas*, and therefore used in eudiometry.

5. Sulphuric and muriatic *acids throw down sulphur, and evolve sulphuretted hydrogen.*

6. Exposed to the air they are slowly changed into sulphates.

7. Have a soapy feel.

8. Sulphuretted hydrogen, passed through them, precipitates the excess of sulphur, and converts them into hydro-sulphurets.

9. Sulphuretted hydro-sulphurets, are formed also, by digesting a hydro-sulphuret upon sulphur, but they do not throw down sulphur when sulphuretted hydrogen is passed through them.†

SULPHURETTED HYDRO-SULPHURET OF POTASSA.

1. Boil sulphur, 1 part, with 3 of the solution of caustic potash, of the common strength.‡

2. Or, decompose the sulphate of potassa, by heating it red hot along with $\frac{1}{4}$ of charcoal, in a crucible: dissolve every thing soluble in hot water, and filter; the theory of these facts will be given farther on.

---

[*] Called also hydrogenized, hydroguretted, and hydrogenated sulphurets, but the name in the text is preferred, because it expresses correctly the composition of these bodies.

[†] Aikin, Vol. 2. p. 364.

[‡] Pearl ashes, water, and sulphur boiled together, produce hydrogenized sulphuret of potassa of a very good quality, so that it is not necessary to use caustic potash; probably sal soda would also answer instead of caustic soda.

3. The color varies in intensity according to the degree of concentration.

4. The principal use made of this preparation is in eudiometry; but the compound with lime is most used, which see.

SULPHURETTED HYDRO-SULPHURET OF SODA.

1. It is almost perfectly identical with the last.

2. The sulphate may be decomposed by charcoal in the same manner, but the appearances are less striking.

SULPHURETTED HYDRO-SULPHURET OF AMMONIA.

1. If liquid ammonia be digested upon sulphur, the action is feeble and not much sulphur is dissolved.

2. But ammonia in its nascent state, dissolves sulphur readily.

3. A preparation of this kind was formerly called *Boyle's fuming liquor*; 3[*] parts slacked lime, 1 muriate of ammonia, 1 flowers of sulphur, and half a part of water, are mingled and a gentle heat applied; the first drops are watery, and as they become deeper colored, the heat is raised till the bottom of the retort becomes slightly red.

4. White fumes are abundantly extricated in the more early stages of the operation, and must have vent from the receiver.

5. The fumes may be all collected in a Woulfe's apparatus; they are more abundant and incoercible in proportion as less water is added.

6. The liquor fumes, as soon as the stopper is withdrawn from the bottle in which it is kept.

7. The fuming is owing to the ammonia in excess, meeting with sulphuretted hydrogen,[†] for when the fuming liquor is digested on sulphur, the ammonia becomes saturated and the fuming ceases.

SULPHURETTED HYDRO-SULPHURET OF LIME.

1. Boil slacked lime with ⅛[‡] sulphur and 10 parts of water, for half an hour or an hour, and shake frequently during the boiling.

2. The fluid is of a fine orange yellow, and deposits crystals on cooling.

3. Decomposition of the sulphate by charcoal and heat, succeeds but imperfectly.

4. For the rest, see general properties.

5. This preparation and the parallel one of potassa are much used in eudiometry, and this is rather preferred, because it affords the most concentrated solution.

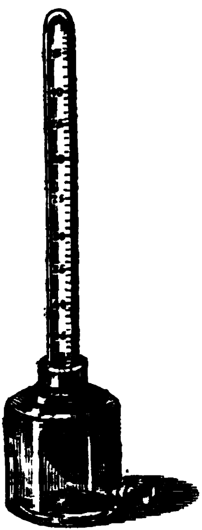
---

[*] 1, *Ure*.

[†] Proceeding, doubtless, from the decomposition of water, by the compound of ammonia and sulphur.

[‡] Equal weights of lime and sulphur.—*Murray*. This is much more sulphur than is needed.

EUDIOMETER OF DR. HOPE.



"This eudiometer consists of a graduated glass tube, sealed at one end, and at the other fitted, by grinding, into the mouth of a tubulated glass bottle, so as to be air tight. Manipulation, with this instrument, is very simple. The tube is filled with gas, the bottle with the liquid which is to act upon the gas. The tube being, under these circumstances, inserted into the mouth of the bottle, by inverting both, the contained gas is made to pass into the bottle. Agitation is next to be resorted to, and time allowed for the absorption to be completed. In the interim, the tubulure is to be occasionally opened under water, by removing a ground stopple with which it is furnished. The gas absorbed, is consequently replaced by water.

"Finally, the stopple must be removed, the tube being previously depressed into water, till this liquid is as high on the outside as within. The graduation being at the same time inspected, the deficit produced by the absorption of oxygen, is thus ascertained."—*Dr. Hare.*

SULPHURETTED HYDRO-SULPHURET OF BARYTA.

1. This compound is formed either by boiling pure baryta (4 parts.) in powder, or in crystals, with water upon sulphur, 1 part, or by decomposing the sulphate of baryta by igniting it along with one sixth charcoal powder for half an hour; then dissolving it in hot water and filtering.

2. This a mixture of sulphuretted hydro-sulphuret and of hydro-sulphuret, which last will crystallize on cooling.

3. See general characters for the rest. This compound is very useful in preparing the salts of baryta; see the muriate and carbonate.

SULPHURETTED HYDRO-SULPHURET OF STRONTIA.

The same in every respect as the last, only the decomposition of the sulphate by charcoal is less striking.

LIQUID SULPHURETS.

1. This name is often given to the hydrogenated sulphurets.

2. Indeed they seem to consist generally of a solution of sulphur in an alkali, combined with more or less of sulphuretted or of bi-sulphuretted hydrogen.

3. According to Proust, a pure liquid sulphuret, without sulphuretted hydrogen, may be formed, by withdrawing the latter by red oxide of mercury.*

SULPHURETTED HYDRO-SULPHURET OF MAGNESIA.

By processes similar to those pointed out above, magnesia gives but feeble indications of combining with sulphur, &c., and is the last of the earths that gives any.

Remarks.—The elaborate researches of Berthollet, (1798,) formerly led us to suppose, that when a base is boiled with sufficient sulphur, a fluid sulphuret was produced, which decomposed water, and generated sulphuretted hydrogen, part of which was exhaled, thus producing the peculiar odor of these preparations, and that the remainder of this gas combined with the sulphuret, and formed what was called hydrogenized sulphuret; and it was thought to be a sufficient proof of the truth of this opinion, that an acid decomposed the preparation, evolving sulphuretted hydrogen and precipitating sulphur abundantly, both of which facts were supposed to arise from the acid seizing the base to form a salt.

More recently, we are taught, that bi-sulphuretted hydrogen is generated in these cases, and that the excess of sulphur is contained in that mode of combination. But I think this cannot be all that happens; for there is great variety in the quantity of sulphuretted hydrogen, which acids evolve, and of sulphur which they precipitate from these preparations. Sometimes, although sulphur is abundantly precipitated, very little gas makes its escape, and at other times it is very abundant. I am persuaded that there is often much sulphur in solution, which is simply dissolved by the entire compound, and is not merely combined with the hydrogen in the form of sulphuretted or bi-sulphuretted hydrogen. My experience would lead me to accord with the following opinion of Dr. Ure.†

1. Sulphuretted hydrogen, sulphur and the alkalies have the property of forming very variable triple combinations.

2. All these combinations contain less sulphuretted hydrogen than the hydro-sulphurets; and

3. The quantity of sulphuretted hydrogen is inversely as the sulphur they contain, and reciprocally.

SULPHURETS.

I. *Sulphurets of alkalies and alkaline earths.*

Remarks.—Until within a few years, it was supposed that the fusion of dry sulphur with the fixed alkalies and alkaline earths, produced a true sulphuret of the alkaline body, and it is still by no means certain that, under particular circumstances, this is not the fact. It is the opinion of Gay Lussac, that a true sulphuret of an oxide is formed, provided the temperature is kept below ignition. "*A une tem-*

---

* Aikin's Dict. Vol. II, p. 363.

† Dict. 2d Ed. p. 756.

perature peu élevee, qui n'atteigne jamais la chaleur rouge, ce corps se combine avec les alcalis sans les décomposer, et forme des sulfures d' oxide." This appears to me so probable, that I shall here preserve a notice of what were, heretofore, regarded as alkaline sulphurets.

1. *Formed by fusion of sulphur with the base*, or decomposition of a sulphate by ignition with charcoal powder.*

2. *Of a liver† color*, if formed with caustic alkalies, *or greenish yellow*, if with their carbonates.

3. *Inodorous, while dry*.

4. Decomposed by a higher degree of heat than that by which they were formed, sulphur being sublimed, and the base left in the bottom of the vessel.

Chemists and physicians‡ were accustomed to use these preparations in solution, but they then ceased to be true sulphurets; for sulphuretted hydrogen was generated, and they passed to a new condition; that of the sulphuretted hydro-sulphurets. In making the preparations, it is of little importance whether we boil the base and sulphur together, or melt them together, and then dissolve them; or whether we dissolve, in hot water, the residuum from the decomposition of the sulphates, by ignition with charcoal; for, in either case, by the decomposition of water, we obtain a compound containing sulphuretted or bi-sulphuretted hydrogen; it is fetid, and acrid, and liberates by the action of acids, precipitated sulphur and sulphuretted hydrogen gas. In all these cases also there is a generation, probably from the oxygen§ of the water, of some of the acids of sulphur, and by spontaneous decomposition, especially if the solution is kept in loosely stopped vessels, the substances pass to the condition of sulphite or sulphate,‖ and thus lose their peculiar properties.

II. *Sulphurets of the metallic bases of the fixed alkalies and alkaline earths.*

---

* In the latter case they were left in mixture with the charcoal, and could scarcely be exhibited pure; it now appears that a metallic sulphuret is produced in this manner.

† Therefore called, in the old language of chemistry, hepar sulphuris or liver of sulphur.

‡ Physicians prepare the sulphuret of potash by taking flowers of sulphur and potash or pearl ashes, equal quantities; they are melted in a covered crucible or skillet, and then kept in a close vessel, but are dissolved for use, in the proportion of two drams in a pint of rain water, and this is used as an external wash. A table spoonful is taken for a dose, twice in a day; used for a variety of eruptions, scald head, psora, &c. In pulmonary consumption it may be given, in the above manner or in form of pills, from two to five grains for a dose, repeated two or three times in a day. It removes or diminishes the hectic fever: it has been used internally as an antidote against metallic poisons and to check excessive salivations from mercury.—*Com'd.*

§ Vauquelin supposed from the oxygen of the alkali.

‖ The preparation from the decomposed sulphate of baryta, is particularly remarkable for passing back to the condition of sulphate, and it often presents distinct prismatic crytals.

It cannot be doubted, that many of the compounds which were formerly regarded as sulphurets of the oxides of metallic bases, were really sulphurets of the metals themselves, and it is now clearly ascertained that they are formed in the following modes and circumstances.

1. *By fusion of the metallic base with sulphur, or by passing its vapor over the metal, ignited in a porcelain tube;* the union often takes place with the disengagement of much heat and light, resembling a combustion, and by many it is regarded as such. Potassium and sodium are the only alkaline bases which we are able to try in this way;* the same thing happens with silicium.

2. *By heating the metallic bases in sulphuretted hydrogen gas*, when the sulphur combines with the metal, often with appearance of combustion, and the hydrogen gas is liberated; potassium and sodium exhibit this phenomenon remarkably.

3. *By passing the same gas, or its solution in water, into the metallic solution*, when sulphurets are precipitated; those metals that are not affected by sulphuretted hydrogen, namely, iron, manganese, nickel, cobalt and uranium, are, like all the other metallic solutions, precipitated as sulphurets, by the hydro-sulphurets of potassa and ammonia.

4. *By heating sulphur to ignition with the oxide of the metal;* the oxygen escapes in sulphurous acid, and the remainder of the sulphur combines with the metal.

5. *By igniting the sulphate of an alkaline oxide with charcoal powder,*† *or by passing the hydrogen gas over the ignited sulphate;* all the sulphates of these bodies are thus reduced at a white heat and if fusible, very quickly. Perhaps the true limit between the sulphurets of the fixed alkalies and alkaline earths, and of their metallic bases, will be found below a red heat for the former, and at or above it for the latter. There cannot be any doubt that true metallic sulphurets are formed, when the alkalies and alkaline earths are ignited with sulphur, or when a sulphate is decomposed, at a similar temperature, by charcoal or hydrogen.‡

It is remarkable that during the decomposition of the sulphates by charcoal, the gases disengaged are found to contain the whole of the oxygen that existed, both in the oxidized base and in the sulphuric acid; and when hydrogen is employed, the water produced, accounts in the same manner, for the whole of the oxygen, and there is in either case, no loss of sulphur, as it all remains combined with the metallic base forming a true metallic sulphuret.

---

* Of the common metals a number, as iron, copper, lead and bismuth, exhibit this phenomenon in a striking manner; the two former shew it in a glass vessel.

† Mr. Berthier enclosed the sulphate in a covered crucible lined with a mixture of clay and charcoal powder.

‡ The limits of this work do not allow me to cite more in detail, the labors of Vauquelin, Ann. de Chim. et de Phys. Vol. VI, 1817, or those of Gay-Lussac, Id. or of Berthier, Id. Vol. XXII, or of Berzelius, Vol. XX. A perspicuous statement drawn from these authorities, may be found in Dr. Turner's Chemistry, 2d Ed. p. 388; I find that it contains every thing of importance in the original memoirs.

When the sulphurets of the metallic bases of the alkaline substances are dissolved in water, they pass at once, to the condition of hydro-sulphurets and sulphuretted hydro-sulphurets. The decomposition of the water appears to be the means of effecting these changes; its oxygen causes the metal to pass to the state of oxide, and its hydrogen with a part of the sulphur forms sulphuretted or bi-sulphuretted hydrogen; some of the acids of sulphur are also formed. When a sulphuret is obtained by the decomposition of sulphate of baryta by charcoal and heat, and subsequent addition of boiling water, there is produced, from a strong solution, a very copious and sudden deposition of white crystalline plates of hydro-sulphuret of baryta, while a part of the fluid appears to remain in the condition of sulphuretted hydro-sulphuret or bi-hydro-sulphuret of baryta. Sulphurous acid or hypo-sulphurous acid is also produced, and combining with a portion of the oxidized base contributes to expel more sulphuretted hydrogen.

In concluding this rather complicated subject, it may be well to call to the recollection of the learner, that the following are its great divisions.

1. *Sulphuretted and bi-sulphuretted hydrogen*, containing sulphur dissolved in hydrogen; one proportion in the former, and two in the latter.
2. *Hydro-sulphurets*, consisting of sulphuretted hydrogen, and an oxidized metallic base* of an alkaline substance; in other words, of an alkali or an earth.†
3. *Sulphuretted hydro-sulphurets*, consisting of bi-sulphuretted hydrogen, and oxidized metallic bases, viz. alkalies and earths; probably containing also variable proportions of sulphur dissolved, besides what is united to the hydrogen.
4. *Sulphurets of the alkalies and earths*, formed below ignition.
5. *Sulphurets of metallic bases*, formed above ignition and containing no sulphuretted hydrogen, nor any uncombined sulphur.

---

* Ammonia being always excepted as having a different constitution, but still, it forms a true hydro-sulphuret, and one of the most useful.

† The common metals are not here brought into view.

SEC. II.—CARBON—carbo—Latin.

1. ITS IMPORTANCE AND WIDE DIFFUSION.

(*a.*) *An element of great interest,* diffused through the animal and vegetable kingdoms, and largely in the mineral, either in the form of carbon or carbonic acid, free or combined.

(*b.*) *Known to the ancients.*—Theophrastus Eresius, pupil and successor of Aristotle, mentions charcoal 300 hundred years before Christ, and Pliny describes the process of burning it.*

2. PRINCIPAL NATURAL FORMS AND VARIETIES.

(*a.*) DIAMOND.—It differs from charcoal, in being a non-conductor of electricity, and in nearly all its physical properties; *still it is pure crystallized carbon.*

The proof rests on the fact, that it is entirely combustible; that it is converted into carbonic acid gas, without any other product; and that it forms steel by cementation with soft iron.† The combustion is effected without difficulty, in pure oxygen gas; under the compound blowpipe, and in melted nitre. It differs from charcoal more in its state of aggregation,‡ than in its chemical relations. Still it is much harder than we imagine; a mass of vegetable charcoal is light, because a great quantity of matter has been expelled in the aëriform state, and thus the substance is made to appear both soft and light; but its integrant particles§ are hard, as will be peceived by grinding them between plates of window glass which they will scratch, and it is stated on the authority of Prof. Leslie, that the sp. gr. of charcoal is really greater than that of the diamond. Carbon exists in a transparent state, in the oils and in alcohol, and in crystals of white sugar, from all of which it is easily developed, by heat, acids, and other agents; it is found also in several gases.

(*b.*) PLUMBAGO, *or black lead.*—The proof that *this is nearly pure carbon,* is the same; it produces carbonic acid by combustion, and there is only a small residuum of iron and earthy impurities.||

(*c.*) ANTHRACITE.—The same remark may be made of this; it *is nearly pure carbon.*

There seems no reason to doubt that *the globules* which I obtained in 1823, from the plumbago and anthracite, by the deflagrator, arose in part, from the earths present in these minerals; but with charcoal, I conceive it to have been otherwise, (see note, p. 358,) and the

---

* Parkes' Essays, Vol. I, 396. † Phil. Trans. 1815, p. 371.

‡ Charcoal is not more different from diamond, than clay or pure pulverulent alumina is from the sapphire; or chalk from Iceland crystal; or pulverulent magnesia, from the same in the boracite; or than quartz nectique, (swimming flint,) from rock crystal.

§ So, the integrant particles of pumice stone and tripoli are hard, although the mass is soft, and that of the former is very light.

|| For its analysis, see Am. Jour. Vol. X, p. 102.

compound blowpipe, evidently effected the fusion of the entire plumbago, including the carbon, the earths and iron.[*]

(*d.*) Bituminous coal.—*The basis of this is carbon,* which, under the name of coak, is obtained, after the bitumen, the inflammable gas, and other volatile ingredients have been expelled by heat. It contains some earthy and metallic impurities, but burns away almost entirely in oxygen gas, producing carbonic acid.

3. Artificial charcoal.

(*a.*) Charcoal *is, after the diamond, the purest form of carbon; it is prepared* in the large way, *by a smothered combustion of billets of wood,* properly arranged, so as to admit a very partial supply of air, through holes at the bottom; the pile is covered with turf, earth or clay, except a few spiracles, or one hole at the top; and these are stopped, when the dark smoke is replaced by clear whitish clouds. The emission of volatile matter, consisting of inflammable gases, vapor of oils, and water, and pyroligneous acid, and other things, chemically or mechanically raised, finally ceases; and the heap is suffered gradually to cool, which takes several days or weeks, according to its size.

The principle of the process is, that the combustion of a portion of the wood produces strong ignition in the remainder, *and thus* expels every thing volatile.

(*b.*) Its formation may be shewn, *by plunging small pieces of wood beneath melted lead or tin,*[†] or beneath sand heated to redness in a crucible, in a furnace;[‡] when cold, it should be immediately removed, and corked up for use.

(*c.*) *Prepared also in cast iron cylinders,* for the manufacture of gun powder,[§] and the charcoal is the same from whatever wood prepared, although alder, dog-wood, and willow have been heretofore preferred. The cylinders are placed across a furnace, and there is vent only for the aërial matter, consisting of inflammable gas, pyroligneous acid[‖] and tar, all of which are useful products.

4. Properties.

(*a.*) *Black, brittle, shining, inodorous,* and easily pulverized; it is so porous that it is easy to blow through it.

---

[*] See Am. Jour. Vol. VI, p. 352.

[†] *Arrangement for class exhibition.*—A small earthen furnace, filled with burning charcoal, is supported by bricks or a stone upon a table, and upon this rests a large ladle nearly full of melted lead, which should be nearly red hot, and the wood held by small tongs is plunged beneath it; the fluid metal will boil vehemently, and the inflammable gas, may be fired as it rises; when all is quiet, the charcoal is developed, and may be cooled beneath mercury.

[‡] Aikin, Vol. II, 235.

[§] Or still more neatly, by wrapping a piece of wood in platina foil, and holding in the flame of alcoholic lamp. The liberated gases take fire and burn brilliantly, and well formed charcoal remains within.—J. G.

[‖] The charcoal made in this manner, is kept from the air when it is to be used for the manufacture of gun powder; it has not more than half the specific gravity of (*b.*) *Unchanged by heat*, in closed vessels, except that it grows firmer, and harder, and blacker, and shrinks; it will then very decidedly scratch glass, and wear a file.[*] With the best pieces, one can write his name on window glass.

(*c.*) *Unaltered by air and water*, and exempt from decay.

(*d.* If well prepared, *it conducts electricity*, but is a bad conductor of heat.[†]

(*e.*) When once thoroughly made, it retains for a long time, its power of conducting electricity. *Heated* without contact of air, *it emits inflammable gases and nitrogen.*[‡]

(*f.*) *After being ignited, it absorbs gases without alteration*;[§] this is shewn by placing on the quicksilver bath, a piece recently extinguished, and covered by a jar. This power is much diminished by pulverizing the charcoal. The following are the results of Saussure, with box wood charcoal, the most powerful species; the time was from 24 to 36 hours; the charcoal was first ignited, cooled in mercury, and then placed in the gas.

Gaseous ammonia 90 times the volume of the charcoal; do. muriatic acid 85; sulphurous acid 65; sulphuretted hydrogen, 55; nitrous oxide, 40; carbonic oxide, 35; olefiant gas, 35; carbonic oxide, 9.42; oxygen, 9.25; azote, 7.5; light gas from moist charcoal 5.; hydrogen, 1.75; very light charcoal scarcely absorbs at all.

The power of absorption in charcoal bears no relation to its chemical attraction for the gas or vapor, which, by heating the charcoal, is in general recovered unaltered.

Those gases that cannot be condensed into the liquid state, are the least absorbed by charcoal, and the reverse is true, very nearly in proportion to the ease with which they are condensed. Vapors

---

common charcoal; although better for gun powder, it is not preferred by the iron manufacturer. The loppings of young trees, called crop wood, are now generally used in England. Abundance of a substance like tar is produced, which Mr. Parkes says is an excellent preservative of wood, against decay and insects.—Essays, Vol. I, p. 399.

The proportion of charcoal obtained from different woods varies from 15 to 26 per cent; the average of 21 trials gave nearly 20 per cent.—Parkes' Essays, Vol. I, p. 406.

Fir gave 18.17, lignum vitæ 17.26, box 20.25, beech 15, oak 17.40, mahogany 15.75.—Allen and Pepys. For a fuller table, see p. 363.

Wood, burned in the open air leaves only about 1-200th, or 1-250th of the wood, but the charcoal is said to contain 1-50th of its weight of alkaline and earthy salts.—Turner.

[*] Even in its common state, good charcoal will wear window glass.

[†] Lampblack is prepared from the combustion of oils and resins. We may collect it by receiving the smoke of a lamp upon a saucer, or by burning a piece of pine knot or rosin, under suspended sacking. In the arts, the refuse resin and pitch are burned in a peculiar furnace, furnished with long flues, terminating in a close chamber, the ceiling of which is covered with porous cloth to catch the soot.

[‡] Mem. d' Arcueil, T. II, p. 484.

[§] Jour. de Phys. T. XXIII, and LVIII, and Ann. de Chim. T. XXXII.

are more easily absorbed than gases, and liquids more easily still. It evidently depends upon the porous form of the charcoal, and plumbago does not possess it at all. The power seems to be analagous to that of capillary attraction in other solids. When oxygen is absorbed, carbonic acid is formed at the end of several months; if charcoal is impregnated with sulphuretted hydrogen, and exposed to the air or to oxygen gas, sulphur is evolved, and water formed, the gas being destroyed, and considerable heat produced, so as, in some cases, to produce in a few minutes, detonation with oxygen gas, and more or less heat is always evolved when gases are absorbed by charcoal.* In general after 24 hours, the absorption is not increased, except in the case of oxygen gas, which goes on absorbing for years, in consequence of the formation of carbonic acid. The gas is easily extracted by the air pump, and during its extrication, cold is produced. Charcoal which has absorbed a gas will give it out entirely by being heated again, and very strikingly with ebullition, by plunging it into boiling hot water. The charcoal can be as effectually prepared for absorbing gases by the air pump as by ignition.† This property is common more or less to all porous bodies; asbestos, silk, meerschaum, adhesive slate, agaric mineral, wool, linen thread, plaster of Paris solidified by water, &c. have been made subjects of similar experiments.‡

(*g.*) *By exposure to the air, charcoal increases in weight*, by absorption of water, air, &c., $\frac{4}{5}$ of which is water.§ By a week's exposure, lignum vitæ gained 9.6 per cent., fir 12.0, box 14.0, beech 16.3, oak 16.5, mahogany 18.0.—*Allen and Pepys.*

(*h.*) *Infusible by any heat* which we can apply, *except that of galvanism.*‖

(*i.*) *Insoluble in water*, although at a red heat, it decomposes that fluid, (vide carburetted hydrogen.)

---

* Proportioned to the rapidity and amount of absorption; 25° in the case of carbonic acid.

† *Quere*—Whether also for conducting galvanism, and for antiseptic agency?

‡ Turner, 2d Ed. p. 285, and Vasel, in Sweigger's Jour.

§ Charcoal absorbs from air more oxygen than nitrogen; when recently ignited and confined in air, over mercury, it left only 8 per cent.; and if from a state of full ignition, it be plunged into water, and then confined in air over mercury, the oxygen is nearly or quite all absorbed, leaving, as is said, pure nitrogen. We are not informed whether the pure oxygen can be recovered by heating the charcoal.

‖ *Fusion of charcoal* by the use of Dr. Hare's Deflagrator. The poles being terminated by well prepared charcoal, a knob of fused matter appears on the copper or negative pole, sometimes half an inch in length, while a cavity, corresponding in position, appears on the zinc or positive pole, and if the pieces are made to change places, the knob and cavity are transferred from side to side. The knob appears to come from the opposite pole, and is evidently derived from the charcoal. It is very difficult to burn, but if heated either in oxygen gas by the sun's rays, or in common air, or mixed with nitrate or chlorate of potash, it produces carbonic acid. On an ignited iron in the air, it wastes slowly away. It is smooth and glistening, with semi-metallic hues; its color gray, or almost black; not fibrous or (*j.*) Plunged into mercury, or merely resting on it, it absorbs much of that metal into its pores.

(*k.*) *Heated in* contact with common *air, it burns away entirely; very rapidly*, and wholly, if immersed *in oxygen gas* in sufficient quantity. A piece of charred bark burns best, and with lively scintillations.

(*l.*) Sulphuric acid boiled on charcoal powder is decomposed, and sulphurous acid gas is liberated.

(*m.*) The decomposition of the sulphates by charcoal, is a striking instance of its action on sulphuric acid.

(*n.*) *To prepare charcoal for clarification;* take that which is well burned, pulverize and sift it; heat it strongly away from the air, as in a crucible with a small hole in the cover, or covered with sand; it must then be bottled tight, till it is wanted.

(*o.*) *Tincture of alkanet*, diluted with water, mixed with well prepared charcoal, and simmered over the fire, and then thrown upon a filter, comes through perfectly limpid. Mixed with common vinegar or wine, a thick froth rises, and the liquors are clear after filtration. It is sometimes necessary to boil the vinegar upon the charcoal.

(*p.*) Ditch, sink, or puddle water, or even that of a surgeon's tub is thus rendered limpid, inodorous, and insipid; and rancid oils are restored by repeated filtration through charcoal.

(*q.*) *The prepared charcoal is an excellent dentifrice;* that from the shell of the cocoa nut is preferred; the charcoal of the kernels of nut fruit is very delicate, and that of carbonized wheat bread is very good.*

(*r.*) Solutions of impure acid of tartar, crude tartar, crude nitre, and other salts are rendered colorless by being boiled with charcoal powder, and are thus made to crystallize in snow white purity.

(*s.*) Impure carbonate of ammonia, sublimed from an equal weight of charcoal powder, is rendered white and deprived of its fœtid smell. Charcoal also destroys the heavy sickening odor arising from oiled and gummed silks, such as those of which hat cases and umbrella coverings are made, and it speedily removes any unpleasant

---

porous; it has no resemblance to charcoal; sinks as readily in strong sulphuric acid, as it before floated on water with its volume half out; its gravity was therefore increased four times, compared with the charcoal in mass.

This observation was first made by myself in March 1823, and has been repeated many times since; with a powerful deflagrator, it constantly occurs. The substance resembles greatly, the residuum found in the iron gas bottles, and there seems no reason to doubt that it proceeds from the volatilization and fusion of the charcoal along with whatever foreign substances it may contain. The objections of Prof. Vanuxem seem to have related to a different substance.—Am. Jour. Vol. IV, p. 371.

* Soot is one of the very best dentifrices; for, besides the carbon, there are the detergent ammoniacal salts, and a bitter principle, and other active agents.

effluvium from clothes, &c. by being wrapped in them. "It also sweetens bilge water."

(*t.*) Malt spirits, distilled from charcoal are deprived of their disagreeable flavor; if too much charcoal is used, the spirit is decomposed, as is vinegar also. Charcoal, for this purpose, is prepared by heating it red hot in a furnace; it is then ground in a mill and barrelled or put to immediate use by having the spirit placed over it.

(*u.*) Eight or ten pounds of the spirit macerated for eight or ten days on two ounces of charcoal, is improved in flavor.

(*v.*) Water become putrid in casks, is restored by filtration through charcoal, especially if a few drops of sulphuric acid be added.

(*w.*) The odor of alcoholic solutions of resins and balsams is not destroyed by charcoal, although their color is; essential oils do not lose their smell.

(*x.*) Distilled waters and many vegetable tinctures, and litmus, and indigo, and other lakes and pigments, become colorless when their aqueous solutions are filtered through charcoal.

(*y.*) Gum-resins, as opium, assafœtida, &c. suspended in water, lose their odors.

(*z.*) Tainted meat is restored by rubbing or boiling it with charcoal powder; and if daily renewed, it preserves meat from putrefaction.

(*aa.*) The inside of water casks is charred to preserve the water from putridity in long voyages, and the ends of posts to keep them from rotting.

(*bb.*) The facts under (*t.*) and (*u.*) are true of rum and other varieties of ardent spirit.

(*cc.*) Proper proportion is essential to success in these experiments.

(*dd.*) *The same portion of charcoal, if re-ignited, may be used repeatedly.*

(*ee.*) *Animal charcoal is a more powerful antiseptic than vegetable;* it is obtained by calcining bones in close vessels.*

(*ff.*) *Charcoal,* if undisturbed when in the act of being formed, *preserves the organization of the substance from which it is derived;* "the wire marks of paper and the thread of linen, are still seen with distinctness," after being carefully burned.

Grains of wheat and rye charred in Herculaneum, by the volcanic eruption, A. D. 79, were easily distinguished from each other, and an arrow head has been charred so as to preserve the form of the feather.—*Parkes.*

(*gg.*) *The charcoal of the heaviest wood requires most air, and gives the most heat,* and is best fitted for the reduction of metallic oxides; "while lighter wood preserves a glowing heat with a less draught of air." If wood be stripped of its bark before it is carbonized, it does not crackle and fly. For black crayons, willow affords the best charcoal, it being uniformly soft. Ivory black is the coal of ignited ivory prepared in close vessels; the common ivory black is often made from bones.

---

* Ann. de Chim. 79, 80; Jour. of Science, IV, 367.

(*hh.*) The durability of charcoal is seen in the figures on the dial plates of steeples, which often stand out in bold relief, while the rest of the wood, painted white, is worn away.

(*ii.*) *Lampblack, ignited* in a crucible, and cooled before it is uncovered, *and* the *charcoal* which is *procured by passing the vapor of oils or of alcohol through ignited tubes, is the purest carbon that art can prepare.* It is an impalpable black powder, and more than twice as heavy as water.*

(*jj.*) *Bistre,* a beautiful brown pigment, *is prepared from an aqueous infusion of wood soot.*

(*kk.*) *Animal charcoal is more dense and less combustible than vegetable,* and contains phosphate of iron; it is distinguished from vegetable, as the latter burns on an ignited iron into white ashes, forming a bitterish liquor with sulphuric acid, but the residuum of animal matter is much less soluble, and forms a compound having a very different taste.†

(*ll.*) *Charcoal is very effectual in depriving treacle or molasses of its peculiar taste;* twenty four pounds, diluted with an equal weight of water, and boiled for half an hour with six pounds of pulverized charcoal, were entirely deprived of the empyreumatic taste and smell, and being strained and evaporated to a proper consistence, had the flavor of good sugar.‡ Honey may be treated in the same manner, and with the same effect.§

(*mm.*) *The due preparation of charcoal is of the last consequence to success in these operations.*—Common charcoal is almost inert; it is indispensable that it be fresh made; or re-ignited, and that it be secluded from the air till it is used.

(*nn.*) *Charcoal is used in polishing brass and copper plates* and lanthorn leaves; in tracing the outlines of drawings, and in giving some peculiar tints to glasses colored in imitation of the gems.‖

(*oo.*) *The ancients knew that charcoal will not decay.*—The piles driven, more than than two thousand years ago, in founding the temple of Ephesus, were charred, and those that support the houses in Venice had undergone the same process. Dr. Robinson, in his introduction to Dr. Black's lectures, says, "About forty years ago, a number of pointed stakes were discovered in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent Julius Cæsar from passing his army over by that ford. They were all charred to a considerable depth, and retained their form completely; and were so firm at the heart, that a vast number of knife handles were manufactured from them, *and sold as antiques*, at a high price."*

---

* Davy's Elements, p. 299. A very pure charcoal is prepared also from sugar and starch.

† Parkes' Essays, Vol. I, p. 414.

‡ Charcoal has been applied to the refining of sugar, and a patent was taken out for it some years ago in London. Mr. Parkes says, that finer loaves of sugar than were manufactured at any other establishment in London, were as he supposes, produced in this manner.

§ Parkes' Essays, Vol. I, p. 419.

‖ Parkes.

5. Polarity.—Electro-positive; it is attracted to the negative pole.

6. Combining weight 6, hydrogen being 1.

7. Medical and other uses.—A preference is entertained by some for charcoal made from particular substances, as from cedar or cork; it should be newly prepared or recently heated.† It is thought to correct a vitiated state of the stomach and bowels, and has been celebrated in some stages of dyspepsia, and in dysentery and other diseases of the alimentary canal. The dose cannot be critical; from 10 grains to a table spoonful may be given, two or three times a day.‡ It is applied with much advantage to foul ulcers, whose fetor it corrects, and in the form of poultice to sores that are tending to gangrene.

8. Miscellaneous.

(*a*.) Charcoal is said to be better if the bark is left on the wood, which should not be split; pieces of six or seven inches in diameter are easily charred.§ Coak is the carbon of mineral coal; it is prepared by a process resembling in principle that for charcoal; it produces an intense fire, and is much used in England in the manufactures, especially of iron.‖ A charcoal is also extracted from peat. The following table shows the proportion of volatile matter, charcoal and ashes, in 100 parts of different woods.—*Ure.*

---

* I saw one of these stakes in the British Museum; the charcoal on the outside and the wood within, were apparently as perfect as the day it was driven.

† If it is to be applied on a foul ulcer or sore, it should be taken red hot from the fire, pulverized immediately in a metallic mortar, and used as soon as cold, and any that remains should be bottled, tight from the air.

‡ Coxe.

§ It is conjectured that in the charring of wood, portions of it are sometimes converted into pyrophorus, and that explosions in powder mills may occasionally be owing to this cause.

‖ One ton of bituminous coal yields from 700 to 1100 lbs. of coak. Much bitumen and other volatile products are lost in the usual way of charring, but Lord Dundonald, by heating the coal in a range of eighteen or twenty stoves, with as little access of air as possible, and conducting the smoke through horizontal tunnels, and finally into a brick tunnel 100 yards long, and covered at top by water, succeeded in obtaining nearly 8 per cent. of bitumen in the form of tar; 28 barrels of it yielded 21 of tar, and the volatile parts gave materials for varnish, besides ammonia.—*Ure.*

	Volatile Matter.	Charcoal.	Ashes.	Charcoal by Proust.	Charcoal by Rumford.
Oak,	76.895	22.682	0.423	20.	43.00
Ash,	81.260	17.972	0.768	17.	
Birch,	80.717	17.491	1.792		
Norway Pine,	80.441	19.204	0.355	20.	44.18
				Black Ash.	
Mahogany,	73.528	25.492	0.980	25.	
Sycamore,	79.20	19.734	1.066		
				Willow.	
Holly,	78.92	19.918	1.162	17.	
				Heart of Oak.	
Scotch Pine,	83.095	16.456	0.449	19.	
Beech,	79.104	19.941	0.955		
Elm,	79.655	19.574	0.761		43.27
Walnut,	78.521	20.663	0.816		
American Maple,	79.331	19.901	0.768		42.23
				Guaiacum.	
Do. Black Beech,	77.512	21.445	1.063	24.	
Laburnum,	74.234	24.586	1.180		
					Poplar.
Lignum Vitæ,	72.643	26.857	0.500		43.57
Sallow,	80.371	18.497	1.132		
					Lime,
Chesnut,	76.304	23.280	0.416		43.59

(*b.*) *Charcoal, in the form of lampblack and plumbago, is among the most enduring of paints, and forms a firm body with oil.* Plumbago is used for lubricating machinery, for making crucibles, for protecting iron from rust, and to give it lustre. Charcoal with oil forms printer's ink; with sulphur and nitre, gunpowder; with iron, by cementation, steel; it is used to exclude or to confine heat; it is a very excellent fuel, and it is employed with advantage, after being thoroughly ignited, to surround that part of lightning rods which enters the ground.—*Thénard.*

(*c.*) *Charcoal is of great utility in reducing the metals,* both in raising the necessary heat and in detaching oxygen from the oxides. Carbon, in the form of diamond is the most beautiful of ornaments, and the best substance to cut glass, and to afford a cutting powder to polish the hardest bodies, diamond itself not excepted. The water of the Seine, rendered turbid by mud in the winter, is purified and made potable, by passing through charcoal, placed between two layers of sand, and these between two others of gravel and pebbles.—*Id.*

(*d.*) *It is exceedingly abundant in nature;* it exists in all animal and vegetable bodies; in all the varieties of natural coal, and bitumens, and petroleum and naptha; in the carbonates of lime, and other mineral carbonates; in carbonic acid, both free in the air, and dissolved in water; and in the carburetted hydrogen gases and carbonic oxide; and its chemical and natural history involves a vast number of interesting and important facts.

SULPHURET OF CARBON.

1. PREPARATION.

(*a.*) A porcelain tube, one inch and a half in diameter, coated with fire lute, and partly filled with fragments of recently ignited charcoal, is placed a little inclined across a furnace; at one end a recurved glass tube dips into water, and the other end is open. The furnace being in action, a fragment of sulphur is pushed along by a wire till it is near the charcoal, taking care to exclude the air as much as possible; the open end of the tube is then stopped, gas passes in abundance, and a liquid collects beneath the water; more bits of sulphur may be introduced, till enough of the liquid is obtained, and it is said that half a pint may be procured in a day.

(*b.*) The following process I find to be a good one. A tube of iron is placed across Black's furnace, as a protection to a tube of porcelain which is passed through it. A glass flask containing flowers of sulphur, coated with lute of sand, clay and rye flour, is connected with one end of the iron tube, and at the other is a glass tube passing into water, contained in a vessel surrounded by ice. Pieces of charcoal, recently ignited, are placed in the porcelain tube, and heat is applied by a chafing dish under the flask; the sulphur is slowly volatilized through the charcoal; the two combine, and the desired yellow liquid drops from the mouth of the tube. The principal point is to bring the sulphur into contact with the charcoal when it is very hot and has ceased to emit gases.

(*c.*) Another process, stated also to be a good one, is to *distil native* iron pyrites, (bi-sulphuret of iron,) with one fifth of its *weight of* charcoal powder.

2. Properties.

(*a.*) After being re-distilled at a heat not exceeding 100° or 110° Fahr., from some dry muriate of lime placed in a retort, it is *colorless, transparent and limpid;*[*] its refractive power very high.

(*b.*) *Taste acrid, pungent, and somewhat aromatic; smell nauseous* and fetid, but unlike that of sulphuretted hydrogen. *Inflammable,* and its combustion produces sulphurous and carbonic acid gases. *Insoluble in water.*

(*c.*) Sp. gr. 1.27; boils at 106° or 110°, does not freeze at 60°; *very volatile,* at 63.5 Fahr. its vapor sustains a column of mercury 7.36 inch high, and *during its evaporation produces so much cold as to freeze mercury.* The thermometer ball is covered with fine lint, moistened with the liquid, and placed under the receiver of an air pump. A spirit thermometer at the same time indicated —80.

(*d.*) Not decomposed, by heat alone, at any temperature; but it is decomposed by being transmitted over ignited iron or copper turnings; also by peroxide of iron; or by heating potassium in its vapor, when there is a brilliant ignition; the sulphur always combines with the metal and liberates the carbon.

(*e.*) It is very combustible, and produces sulphurous and carbonic acid; a little sulphur remains unburnt. Placed in oxygen gas or deutoxide of nitrogen, it renders it explosive. Soluble in volatile oils, in ether and in alcohol, and precipitable by water.

---

[*] Sometimes a little milky and opaque at first, but becomes limpid the next day.

(*f.*) Evaporation from water causes it to congeal.

3. Composition.—85 sulphur to 15 carbon, and it is supposed to contain 2 proportions of sulphur 16 × 2 = 32 and 1 carbon 6 = 38 for its chemical equivalent. This compound was called alcohol of sulphur by Lampadius, its discoverer.*

Hydro-xanthic acid.—(ξανθος, yellow.)

The sulphuret of carbon is generally unaffected by acids, but the nitro-muriatic acid produces from it a yellow acid, whose nature is not yet exactly ascertained.† Its discoverer, M. Zeise, (Copenhagen,) regards it as a compound of sulphur and carbon for a base, with hydrogen for an acidifier. It combines with alkalies, neutralizing them, and forming peculiar crystallizable salts. The subject seems to need farther examination.‡

Remark.—It was announced last year, in Paris, that phosphorus, remaining six or eight months in bi-sulphuret of carbon, attracted away the sulphur, and left the carbon to crystallize into true diamond; it was said that the Parisian jewellers pronounced it to be genuine, but the latest accounts state that the small crystals obtained appear to be siliceous.

CARBONIC ACID.

1. Combustion of carbon in various forms.

(*a.*) It has been already mentioned, that Sir Isaac Newton supposed the diamond to be a coagulated combustible, because it refracted light so powerfully. This sagacious conjecture has been confirmed by the actual combustion of the diamond, and the products having been collected are found to be carbonic acid.§

---

* Crell's Annals, 1796, II.—Cited by Turner.

† Berzelius supposes it to be a compound of muriatic, carbonic and sulphurous acid gases.

‡ Ann. de Chim. et de Phys. Vol. XXI, and Ann. Phil. N. S. Vol. IV. Thénard, 5th ed. Vol. I, p. 440.

§ The Emperor Francis I, exposed a quantity of diamonds and rubies to an intense heat, the rubies remained unaltered, but the diamonds disappeared. The Florentine academicians, by means of the large burning glass of Tschirhaucen, in the presence of Cosmo III, Duke of Tuscany, dissipated several diamonds in the year 1694. These experiments were repeated with equal success by Darcet, Rouelle, Macquer, and other French chemists, who ascertained that the diamond was not merely dissipated, but that it actually burnt with a visible flame. Count de Sternberg, a Bohemian gentleman, fastened a diamond to red hot iron, and plunged it into oxygen gas, when the combustion of the iron set fire to the diamond, which burnt with a very brilliant flame. Lavoisier and Cadet proved that the diamond does not burn after the oxygen gas is exhausted. But these experiments went only to prove that the diamond is combustible. No attention had been paid to the products of the combustion, until Lavoisier, in 1777, undertook a series of experiments on a large scale, to ascertain this point. The result was found to be, that the diamond when burnt in oxygen gas, is converted wholly into carbonic acid gas. The conclusion (*b.*) A coated glass or porcelain tube filled with charcoal that has been heated till it has ceased to yield any gas, is placed across a furnace and ignited; one end being connected with a gazometer to afford oxygen gas or common air; the other with a pneumatic apparatus to receive the gas; by adding another gazometer, the gas may be made to pass repeatedly back and forward.

(*c.*) Diamond, charcoal, plumbago and anthracite, or any varieties of carbon may be treated in the same manner, as was done by Messrs. Allen and Pepys, in their celebrated experiments; they used a platinum tube to contain the diamond and other forms of carbon, and their gazometers were placed over mercury.

(*d.*) *Burn charcoal in a bottle or jar of oxygen gas;* if a piece of well charred bark be used, the combustion is attended with brilliant scintillations; otherwise with only a bright glow.

(*e.*) *Burn any kind of wood, or a taper, in a bottle of common air, or of oxygen gas, and carbonic acid will be formed,* as may be evinced by the test of lime water, which produces a milky precipitate.

(*f.*) *Diamond is easily made to burn under the compound blowpipe,*[*] and wastes entirely away. If the combustion be stopped in its progress, the surface of the diamond will be found, not carbonized, but indented and dull, as if it had been corroded and then washed. In my experiments it had the appearance of superficial fusion.

(*g.*) An elegant apparatus for the combustion of diamond, is figured by Mr. Brande, in his elements, and copied by Dr. Henry,[†] by which the diamond may be burned, and the products collected. By combustion, it is rapidly diminished, and carbonic acid is abundantly precipitated by admitting lime water.

(*h.*) According to the experiments of different eminent chemists,[‡] 28 or 29 grains of any pure carbon, require 71 or 72 of oxygen and give 100 carbonic acid; 201 cubic inches of oxygen by bulk, require 28 or 29 grains of charcoal. Mr. Dalton assumes the *composition of carbonic acid* to be,[§] in round numbers, 28 *carbon to*

---

that diamond is carbon, was unavoidable. In 1785, Guyton Morveau, found that the diamond, when dropped into melted nitre, burns without any residuum, and in a manner analogous to charcoal. Dr. Tennant also burnt the diamond in nitre, and found that carbonic acid gas was the only product.—(Phil. Trans. 1797.) Guyton Morveau observed, that the diamond burns at three different temperatures, and although some of his conclusions were erroneous, for instance, that the diamond can be converted into a substance resembling charcoal, and that charcoal is an oxide of carbon, still he fully established the fact that diamond is by combustion, converted into carbonic acid.

[*] See Am. Jour. Vol. VI, p. 349.

[†] Vol. I, p. 342, 10th Ed.

[‡] Carbon, 28.60; oxygen, 71.40=100. Carbon, 27.376; oxygen, 72.624=100. Allen and Pepys, Clement and Desormes, Wollaston, Gay-Lussac, and Berzelius. See Henry, 10th Ed. Vol. I, p. 344.

[§] The precise proportions appear to be 72.72 of oxygen, and 27.27 of carbon, which corresponds with 2 proportions of oxygen and of 1 carbon.—*Murray*.

72 *oxygen*, and all the results come so near to this, that we may venture to neglect the fractions. The composition of carbonic acid is a problem of great importance, for whenever it is produced, we infer the presence of carbon in the proportion now stated.

(*i.*) *Oxygen gas, by uniting with charcoal, suffers neither contraction nor expansion*, but increases in specific gravity, so that 100 cubic inches weigh, at the medium temperature and pressure, 46.59 grains, or about one and a half the weight of common air.*

These methods of obtaining carbonic acid gas, are put in practice only to demonstrate its composition; they are never resorted to when the object is to obtain the gas in large quantities; then it is always extracted from some of its natural combinations.

2. OTHER MODES OF OBTAINING CARBONIC ACID GAS.

(*a.*) *Procured from marble powder, or chalk with dilute sulphuric or muriatic acid.*† The proportions with sulphuric acid, may be about 6 parts by weight, of water, to 1 acid, and 1½ marble powder; apparatus—a retort, flask, or bottle, with a glass tube, bent twice at right angles, and turned up at the end of delivery; it may be thrust through a cork bored by a tapering hot iron; the residuum will be sulphate of lime.

(*b.*) *Heat marble powder or chalk, red hot, in an iron bottle;* a quart affords a barrel of gas, and the residuum is brought almost to the condition of quick lime.

3. DECOMPOSITION.

(*a.*) *Decomposed by repeated electrical discharges*, over mercury; becomes carbonous oxide,‡ and oxygen gas.

The undecomposed carbonic acid, being washed out by lime water, or potassa, and an electric discharge passed through the remainder, it explodes and becomes again carbonic acid.

(*b.*) A mixture of hydrogen and carbonic acid, being heated in the same manner, water and oxide of carbon are obtained.

(*c.*) Carbonic acid, as it exists in the carbonate of lime, and of baryta, and probably strontia, is easily decomposed by igniting the pulverized carbonate with iron filings, when oxide of carbon is produced, as will be shewn in connexion with that substance.

(*d.*) Potassium heated in carbonic acid gas, in the proportion of 5 grains to 3 cubic inches, inflames, and charcoal is precipitated,‖

---

* For the statements of different writers, see Henry.

† Muriatic acid, mixed with 2 or 3 parts of water, is perhaps preferable, because the sulphuric acid forms an insoluble compound with the lime, and clogs the effervescence.

‡ Whose propertes will be soon explained.

‖ I am accustomed to exhibit this beautiful experiment by the following arrangement.—A flask, with dilute sulphuric acid and marble powder, is fitted with a cork and tube bent twice at right angles, through which carbonic acid gas flows to the bottom of another flask, and expels the air, or the gas may be introduced in a similar manner (*e.*) *Carbonic acid*, contained in carbonate of lime, or of soda, *is decomposed by phosphorus*, and the carbon appears in the form of charcoal.

(*f.*) It is done by taking a glass tube ⅛ of an inch wide, and 20 inches long; it is sealed at one end, and coated with sand and clay, to within an inch of the end; phosphorus is placed there, and marble powder, or better, carbonate of soda, dried in a sufficient heat; the part containing the carbonate is heated red hot, and then the phosphorus is sublimed through it, and the heat continued for some minutes; charcoal is found mixed with a phosphate.*

(*g.*) In Dr. Pearson's experiment, 200 grains of phosphorus, and 800 carbonate of soda, gave 40 grains charcoal.†

(*h.*) If phosphorus be boiled in a solution of carbonate of soda, it becomes black in consequence of the developement of charcoal; it is done in a small flask, and the process occupies an hour.

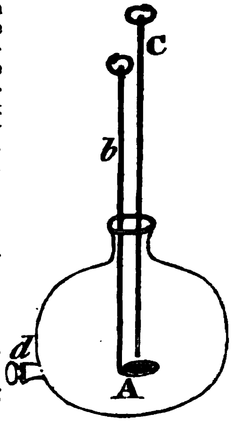
4. PROPERTIES.

(*a.*) *Carbonic acid gas is fatal to animal life;* if we confine a mouse or other small animal in this gas, it will speedily die. Butterflies and other insects may be killed in this manner, or by heat alone, without injuring their beauty. This gas kills both by suffocation and by a deadly influence of its own.

(*b.*) *It extinguishes combustion;* lower a pendent candle into it, and withdrawing it immediately, drop it into oxygen gas; it is extinguished and relighted alternately. Gun powder burns in this gas.‡

---

from a small gazometer. A tray of platinum, with a lump of potassium, is slipped into the flask, taking care at the same time, not to let in the air or spill the carbonic acid; a tube, twice bent at right angles, is then adapted, and dips into a glass containing mercury; live coals are applied beneath the tray of potassium, and just at the point of the fusion of plate glass, the potassium inflames with bright light, regenerated potassa fills the flask with white fumes, and charcoal precipitates, mixed with the potassium. A green flask would probably be better, as enduring more heat; sometimes the experiment succeeds with difficulty, and the bottom of the flask is indented. N. B. The second tube and the mercury may be dispensed with, provided we cork the flask *rather loosely*, so as to allow the gas to escape a little by expansion.



[*] Phil. Trans. 1791, p. 182.

[†] Phil. Trans. 1792, p. 289.

[‡] A, Large glass globe with a wide neck filled with carbonic acid gas.

b, Iron or copper spoon with gun powder in it.

C, An iron rod heated red hot at the lower end to inflame a few grains of gunpowder.

d, Orifice stopped with a cork, which being withdrawn, the gas runs in a visible current and fluctuates.

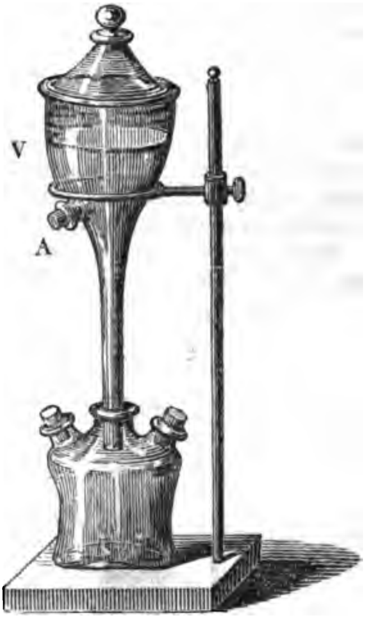
A candle cannot burn in atmospherical air, containing one fourth part, by measure, of carbonic acid.

(*c.*) *Mix smoke with this gas*, by extinguishing in it a burning chip or paper, or by burning a cork with a red hot iron borer, at the vessel's mouth, or better by exploding gun powder in a pendent spoon, in a jar, or globe filled with carbonic acid; see the figure on p. 368.

(*d.*) *The gas is thus rendered visible*, and exhibits distinct fluctuations and currents.

(*e.*) Butterflies and other insects of delicate colors are killed in this gas, and better than by sulphurous acid gas.*

(*f.*) By a cylindrical jar, containing carbonic acid gas and a little water, with the aid of a pendent candle, we may show the phenomena of the damp in wells and caverns. In the annexed apparatus, two ounces of the carbonate of ammonia, and half as much deep orange colored nitrous acid, being placed in the three necked bottle, will evolve carbonic acid gas, which will thus be rendered visible in its ascent, and in its overflow beneath the cover of the upper vessel. This being removed and a candle introduced, it will be extinguished. The gas can be drawn off at A; its current will be visible, and it will extinguish a burning taper held in its course; or it can be drawn like a liquid into any other vessel containing a lighted candle which it will thus put out. If either orifice of the bottle be opened, all the gas in the upper vessel will flow out.—*Dr. Hare.* A long necked funnel may be substituted for the upper vessel.



(*g.*) Sp. gr. 1.527; 100 cub. inch. weigh at 60° Fahr. and 30 in. Bar. 46.59, whereas air weighs 30.50.†

(*h.*) *We may pour the contents of one jar into another*, and examine by a pendent candle how high the gases rise.

(*i.*) *We may collect it by a bent tube* passing into a bottle filled only with common air, which it will expel.

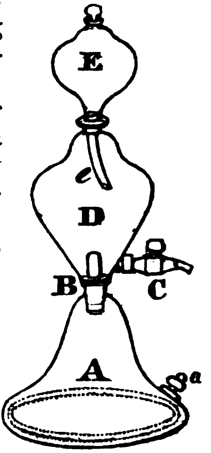
---

* Entomologists prefer to kill them simply by means of heat, immersing them in boiling water, in close vessels.

† It is said that Dr. Prout has recently ascertained that it is as high at least as 31 grs. Addenda to Turner, 2d edition.

(*j.*) *The absorption of this gas by water, is slow* if merely standing over it, but rapid, if agitated with the water in a bottle.

(*k.*) *Nooth's apparatus* is an elegant one for impregnating water with this gas; it combines agitation and moderate pressure.



A, The pedestal and containing vessel for the marble powder and acid; *a*, an orifice for pouring in the diluted acid which should be mixed previously with water and allowed to cool.

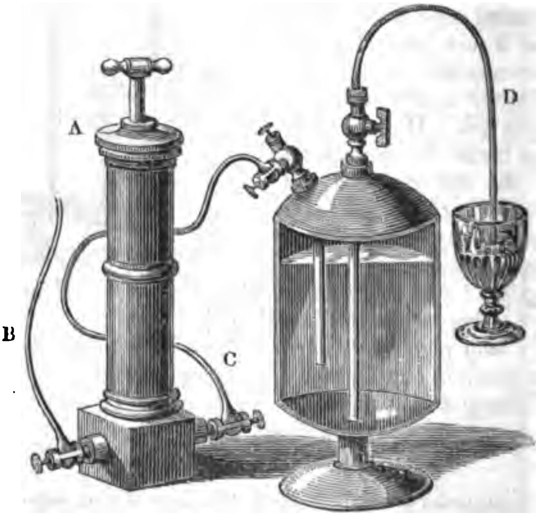
B, The neck of the vessel to contain the water which is to be impregnated; this neck contains a glass cylinder pierced longitudinally with capillary ducts, and also a plano-convex lens, which operates as a valve.

D, The containing vessel furnished with a stop cock at C.

E, A vessel of retreat for the water. As the gas rises into the middle vessel, it causes the fluid, by means of the bent tube *e*, to mount into E, thus producing hydrostatic pressure, and favoring the combination of the water with the gas.

Much more powerful instruments are known in the arts.* The following is from Dr. Hare.

IMPREGNATION OF WATER WITH CARBONIC ACID.



" A condenser, A, is fastened at bottom, into a block of brass, which is furnished with a conical brass screw, by means of which, it is easily attached firmly to the floor. In this brass block are cavities for the two valves, one opening inwards from the pipe, B, the other outwards, towards the pipe, C. The pipe, B, communicates with a reservoir of gas which the condenser draws in, and forces through the other pipe into a strong copper vessel containing the water. The front part is represented as removed in order to expose the inside to inspection."

---

* Phil. Trans. 1803; Dr. Henry's Apparatus.

"If due care be taken to expel all the air in the vessel before the impregnation is commenced, the water will take up as many times its bulk of gas, as the pressure employed exceeds that of the atmosphere."

"When duly saturated, the water may be withdrawn at pleasure, by means of the syphon, D, of which one leg descends from the vertex of the vessel, to the bottom, while the other is conveniently situated for filling a goblet."

(*l.*) The gas washed to free it from any sulphuric acid, and passed up into litmus infusion, reddens it fugaciously.

(*m.*) *Liquid** *carbonic acid gives up its gas by boiling*, and by being placed under the exhausted receiver.

(*n.*) *Litmus water, reddened by this acid, is restored by air pump exhaustion, or by boiling.*† This gas is liberated from water by freezing, which gives the fluid a spongy appearance.

(*o.*) *Lime water is a test of carbonic acid;* it is applied by pouring the liquid acid into it—by suffering the gas to pass into a tall inverted tube closed at the top and filled with lime water, or by receiving the gas in a bottle and washing it with lime water.

(*p.*) *An excess of carbonic acid redissolves the precipitate*, and then more lime water precipitates it again, and so on without limit.

(*q.*) Burn a candle, a stick, or any common combustible, in a bottle of air or oxygen gas, and examine by lime water for carbonic acid; if present there will be a milky precipitate.

(*r.*) *Carbon is a principle of those substances which, by burning, give a gas not rapidly absorbed by water, and which precipitates lime water; the precipitate being soluble in muriatic acid, with effervescence.*

(*s.*) *This gas is an antiseptic*, and therefore useful in putrid diseases, and externally in ulcers. Cataplasms are made with yeast and other fermenting materials.

(*t.*) Meat suspended in carbonic acid, especially if the gas be frequently renewed, keeps much longer than in common air.

(*u.*) *Carbonic acid promotes vegetation*, especially when in the liquid form and applied to the roots; also, as an atmosphere, provided it does not exceed one eighth of the whole ; beyond that it is injurious.

---

* At a common temperature and pressure, water absorbs its own volume of gas; twice its volume under a double pressure, and so on in the same ratio.

† Tincture of alkanet diluted and slightly blued by ammonia, is decidedly reddened when agitated in a vial with carbonic acid gas.

When the above solution is boiled so as to expel the carbonic acid, it resumes its original blue color.

(*v.*) *This gas exists in fermented liquids ;* we may collect it from any fermenting mixture, or from bottled cider, beer, porter, &c. and it will prove to be carbonic acid.

(*w.*) *This may be shewn by drawing the cork under water*—the mouth of the bottle being immersed, the gas, at least what is spontaneously disengaged, will collect at top, and the rest may be obtained by boiling the fluid in a proper gas apparatus.

5. MISCELLANEOUS.

(*a.*) *Carbonic acid gas,* on account of its gravity, *is often found at the bottom of wells and caverns,* as in the grotto Del Cani, near Naples, and thus often destroys those who incautiously descend into them ; by letting down a candle, it may always be determined whether the place is safe.

(*b.*) *As the combustion of charcoal,* and other carbonaceous substances, *always generates carbonic acid, it is unsafe ever to remain* in a confined situation, *in such an atmosphere ;* in both these modes many lives are destroyed. When it is pure, it produces a spasm of the glottis, and suffocation ensues ; if so much diluted as to pass into the lungs, it operates as a narcotic poison.*

(*c.*) *There are many other gases evolved in combustion, and all of them are deadly ;* nitrogen is always present in such cases, and frequently carburetted hydrogen, gaseous oxide of carbon, ammonia, and various vapors, as of pyroligneous acid, &c.

(*d.*) *Fire should, therefore, always be made under a good drawing vent.*

(*e.*) *Carbonic acid is eminently salutary in the stomach, although fatal in the lungs ;* witness the native and artificial acidulous waters ; its action in the primæ viæ is that of a mild stimulant. With common air, it exists, dissolved, in all natural waters, and imparts to them pungency ; hence the flatness of boiled water, or of that which has been exposed to air pump exhaustion.

(*f.*) *Carbonic acid gas is the principal agent in raising bread ;* it is generated in the fermenting mixtures, as yeast, the sediment of beer,† &c., and the native or artificial acidulous waters will inflate dough and make it light.

(*g.*) *Carbonic acid exists every where in the atmosphere ;* it was found on the top of Mount Blanc, by Saussure,‡ and aëronauts have brought it down from the greatest heights to which man has ascended; in general, the proportion is very uniform. A pellicle is formed on lime water, by exposure to the air; it contains $\frac{1}{100}$ carbonic acid, as formerly stated; according to Dalton, $\frac{1}{1000}$, or even less.

---

* It is supposed by many, that charcoal, *when burning without smoke,* is harmless, and that the anthracite coal does not produce a noxious gas ; both these are very dangerous popular errors ; the deadly carbonic acid gas is rapidly formed from both, *during the whole time that they are burning.*

† Called in this country *emptyings.*

‡ Jour. de Phys. XVII, p. 202.

(*h.*) Although produced in enormous quantities by respiration, combustion, and other processes, it is scarcely found to exist in greater proportion in large towns than in the country; doubtless the winds prevent its accumulation. At sea, however, only two leagues from Dieppe, there was so little that it scarcely affected barytic water.*

(*i.*) Caustic alkalies absorb carbonic acid gas entirely, and thus separate it from other gases.

(*j.*) *Vegetation appears to be the grand means of preserving the purity of the atmosphere;* it decomposes the carbonic acid, absorbs its carbon for food, and lets loose its oxygen.

It is true that vegetables emit carbonic acid in the night, but in smaller quantity than that which they decompose in the day.†

(*k.*) *Carbonic acid is visible in the sunshine,* as it descends into a vessel of common air, because, on account of its great weight, it produces unequal refraction in the light, and thus creates a disturbed image.

6. RESPIRATION.

(*a.*) About 8 or 8½ per cent. of carbonic acid is thrown from the human lungs in respiration, at every expiration, and only 10 per cent. when the contact is rendered almost as frequently as possible; a similar result happens with the whole animal creation.

(*b.*) About 11 oz. Troy, of carbon, are thus daily detached from the blood, and of course more than twice the weight of a living man in a year.

(*c.*) Thus one great office of respiration is, the decarbonization of the blood.

(*d.*) *The production of animal heat is also intimately connected with this process;* venous blood becomes arterial in the lungs, and there acquires its florid color, and emits its excess of carbon, and its capacity for heat, according to the experiments of Dr. Crawford,‡ is enlarged from .892, which expresses the capacity of venous blood, to .1030; thus the heat that would be evolved from the union of the carbon with the oxygen, is absorbed, and again given out when the arterial blood becomes venous, that is, all over the body.||

(*e.*) There can be no doubt that animal heat is connected also with the nervous power, with secretion, and perhaps with other vital agencies.

---

* Ann. Phil. N. S. VI, p. 75.

† See Thomson's Chemistry.

‡ The experiments of Dr. J. Davy, do not appear to have set aside those of Dr. Crawford.

|| In a note on respiration, in Parkes' Chem. Chat. the following facts are stated. The human heart gives 100,000 strokes in 24 hours, 4000 strokes in an hour, and 66 or 67 in a minute, and 350 pounds of blood pass through it in that time; 25 pounds is the whole amount in the body of a common sized man; this passes through the heart 14 times in an hour. The aorta of a whale is one foot in diameter, and 10 or 15 gallons of blood (half a barrel,) are sent out at every stroke with vast force.

(*f*.) Lime or barytic water is precipitated by blowing through it with a tube; or by agitation in air which has been breathed.

7. Combining weight.—The weight of carbon is 6, and carbonic acid being a compound of 2 proportions of oxygen, and 1 of carbon, its equivalent will be 16+6=22.

In volumes, Gay-Lussac estimates it constitution to be 1 gaseous carbon, and 1 oxygen, condensed into 1 volume. As oxygen undergoes no change of volume, by combining with carbon, and as 100 cubic inches of carbonic acid weigh 46.597 grains, it follows that the amount of carbon in vapor will be 46.597 – 33.888, the weight of 100 cubic inches of oxygen, =12.709 grs. of carbon; and as 12.709 : 33.888 : : 6 to 16, and 6 being the combining proportion of carbon, it follows that carbonic acid is composed as above.*

8. Polarity.—Like other acids, it is evolved at the positive pole, and is therefore *electro negative.*

9. Liquefaction of carbonic acid.

Mr. Faraday† *effected this by cold and pressure.* He contrived to extricate the carbonic acid gas from sulphuric acid and carbonate of ammonia, brought together at the moment, and after the bent glass tube in which they were contained was sealed, the other end of the tube was kept cold by a freezing mixture, and the gas, subjected to its own enormous pressure, aided by cold, became fluid. These experiments are very hazardous, as it is a more difficult gas to condense than any with which Mr. Faraday succeeded; very strong tubes were required and yet they often exploded.

10. Properties.

(*a.*) *Limpid, colorless, very fluid;* floating on the other fluids in the tube; distils readily and rapidly between 0 and 32°; refractive power less than that of water, not altered by increase of cold.

When it was attempted to open the tubes, they always burst with powerful explosions; at 32° the pressure was equal to 36 atmospheres.

Sir H. Davy, in a communication to the Royal Society, suggested the application of condensed gases as a moving force, capable of being increased or diminished by slight variations of temperature. It would be necessary only to let loose a little of the condensed carbonic acid, to produce a powerful movement; condensed nitrogen would be still more powerful, and hydrogen would exert a tremendous force. No furnaces would be necessary, but mere variations between sunshine and shade might perhaps be sufficient to vary the energy of the power. It is obvious, however, that the danger of explosion would be great.

11. Discovery.—Dr. Black discovered carbonic acid in 1755, or 6, and thus laid the foundations of the pneumatic chemistry; he called

---

* Turner.

† Phil. Trans. 1823, p. 193.

it *fixed air.*[*] Its composition was first demonstrated in 1772, by Lavoisier, who, as already stated, proved that the diamond, by being burned, becomes carbonic acid gas.

12. NATURAL ORIGIN.

Carbonic acid gas is formed abundantly by the respiration of animals; from our candles and lamps, and from our fire-places, and from furnaces, from fermentation and putrefaction it is perpetually rising into the air. It forms nearly half, $\frac{44}{100}$, of the beds and mountains of marble and limestone, and exists in various other natural carbonates, and abundantly in shells. Its fatal prevalence appears to be prevented by the fact that vegetables during their growth decompose this gas, absorbing its carbon for food, and liberating the oxygen to recruit the waste of the atmosphere.

The late Dr. Woodhouse, proved by many experiments, that whenever vegetables emit oxygen gas, it is from the decomposition of carbonic acid present in the air, and dissolved in the waters which they imbibe. He justly rejected the idea that they give out oxygen gas of themselves, or from the decomposition of water.[†]

13. MEDICAL AND ECONOMICAL USES.

It is highly salutary in the brisk and acidulous natural mineral waters, such as those of Saratoga and Ballston, and in imitations of them by art, either with or without saline substances; in fermented liquors, to which this agent imparts life and pungency, and in a degree to all natural waters. It operates as a tonic, diuretic and antiseptic remedy. It is said to be very useful in the hemorrhoids or piles; it is a reagent in the laboratory.

CARBONATES.

General facts and characters.

Some of them have been long known, and were used before the discovery of the power of carbonic acid to neutralize the alkalies.

(*a.*) The carbonates effervesce with acids, and emit carbonic acid.

(*b.*) They are decomposed by heat, more or less violent; the gas being expelled, and the base remains.[‡] Potassa, soda and lithia, are exceptions.

(*c.*) Alkaline carbonates turn the vegetable blues green, and have an alkaline taste.

(*d.*) They are soluble in water, and the carbonates of the alkaline earths become so by an excess of carbonic acid.

---

[*] The miners, alluding to its effect on respiration, call it *choke-damp.*

[†] See 2d volume of Nicholson's Journal, 8vo. and an abstract in Mease's Domestic Encyclopedia.

[‡] Charcoal is added to some of the carbonates before ignition, and aids in producing the effect; sometimes by decomposing the carbonic acid itself. Baryta and strontia are usually managed in this manner.

(*e.*) They contain either one equivalent of acid to one of base, and are then called carbonates; or two of acid to one of base, and are then called bi-carbonates.

(*f.*) Most of the carbonates exist native, and all may be formed by passing carbonic acid gas through the base, suspended or dissolved in water.

CARBONATE AND BI-CARBONATE OF POTASSA.*—CARBONATE.

1. NAME AND HISTORY.

(*a.*) In the shops called *salt of tartar, salt of wormwood and pearl-ashes.*

(*b.*) *The carbonate of potassa was always considered as the pure alkali*, till Dr. Black discovered the error.†

(*c.*) *The alkalies as found in the shops, under the names of pearl-ashes, sal soda and volatile alkali*, have been called sub-carbonates, and when saturated with carbonic acid they were called carbonates. As it is ascertained that in the former state they consist of one equivalent of alkali and one of base, and in the latter of two equivalents of acid and one of base, the last is now called bi-carbonate and the first simply carbonate.

2. PREPARATION.—For common purposes there is no occasion to prepare this salt artificially, but for instruction or to attain greater purity, it may be done,

(*a.*) *By deflagrating tartar with one eighth of pure nitre.*

(*b.*) *Tartar may be calcined in a crucible*, which destroys the tartaric acid; lixiviation and evaporation give about one third part of dry carbonate.

(*c.*) *Nitre being mixed with one fourth of dry powdered charcoal, and thrown into a red hot crucible*, both acids are destroyed, and the alkali obtained amounts to rather less than one half of the nitre employed.‡ The alkali obtained from tartar may be made to crystallize, and the crystals contain carbonic acid 22, 1 proportion; potassa 48, 1 proportion; water 18, 2 proportions, =88, the equivalent.

(*d.*) *Caustic potash absorbs carbonic acid gas with avidity*, and when saturated, and evaporated to dryness, it forms the carbonate of potash, containing, according to an average of three analyses, carbonic acid 31.50, alkali 68.83. The ignited carbonate contains no water, but there is in common salt of tartar from twelve to sixteen per cent.

---

* For the natural history of the carbonate, see potassa. In vegetables, it is probably combined, for the greater part, with acids, which being destroyed by the fire, carbonic acid is thus formed and unites to the alkali.

† It has been already mentioned that the old chemical books describe effervescence with acids, as a test of alkalies; whereas this property belongs to their carbonates. Dr. Black first proved that this is their common state, that the carbonic acid greatly allays their acrimony, and that they are caustic only when deprived of it.

‡ A little sulphate and muriate of potassa, and a little silica, are apt to remain in the alkali thus prepared, and it is difficult to remove them.

3. Properties.

(*a.*) As it occurs in the shops, it is never crystallized; the pearl-ashes are always a white porous mass; the potashes are firm, and of a grey, reddish, or dark color, and both are impure, being mixed, usually with silica and different salts, as the muriate and sulphate of potassa.

(*b.*) *Very deliquescent*, and in the air, becomes in a few hours, semi-fluid.

(*c.*) *Gives carbonic acid gas by other acids and by heat;* alkaline to the taste, turns blue vegetables green, and is even somewhat acrimonious, but does not *destroy the texture of woolen cloth.*

(*d.*) *Does not* absorb carbonic acid from the air, nor yield anything to alcohol.

(*e.*) *Soluble in less than* 1 *part of cold water*, and cannot be freed from it without considerable heat.

(*f.*) *Taste much milder than that of the caustic alkalies.*

4. Methods of determining the quantity of real alkali.

(*a.*) *Potassa precipitates alumina from alum*, which its impurities will not do; hence, the quantity of earth thus precipitated, indicates the proportion of alkali.

(*b.*) *By nitric acid*, which does not dissolve the impurities of the salt.*

(*c.*) *The proportion of carbonic acid indicates the proportion of alkali.*—In a balance, place in one scale the alkali and diluted sulphuric acid, in different vessels; counterpoise them; then add the acid to the alkali; the loss of weight is carbonic acid, and implies about twice as much alkali.

(*d.*) *The solvbility in water is a tolerable criterion.*—Most of the impurities, especially sulphate of potassa and silica, being insoluble,

---

* TABLE BY VAUQUELIN.

	Potash.	Sulphate of Potash.	Muriate of Potash.	Insoluble Residue.	Carbonic acid and Water.	Total.
Potash of Russia,	772	65	5	56	254	1152
“ America,	857	154	20	2	119	1152
American Pearlash,	754	80	4	6	308	1152
Potash of Treves,	720	165	44	24	199	1152
“ Dantzic,	603	152	14	79	304	1152
“ Vosges,	444	148	510	24	304	1440

N. B. American Pearlash contains about 65 per cent. of pure alkali.—Thomson quoted from Ann. de Chim. XI, 298.

or difficultly soluble, the proportion of residuum, therefore, indicates the amount of impurities. If the impurities are soluble, as muriate of soda, then the sulphuric acid becomes a test; 355 *grains of this acid of the sp. gr.* 1.141, (which is the best for this purpose,) *saturate* 100 *grains of carbonate of potassa.* Dissolve this in water, add the diluted acid by degrees, till the alkali is neutralized, and weigh the remaining acid; then as 355 : 100 : : the acid expended to the proportion of alkali.[*]

BI-CARBONATE OF POTASSA.

1. PREPARATION.

(*a.*) *In Nooth's, or a similar machine, pass carbonic acid gas, to saturation, through a solution of potassa,* or of the carbonate in 5 parts of water. The bi-carbonate crystallizes as the process goes forward, or afterwards by gentle evaporation.

(*b.*) Or, we may *take* 1[†] *part of carbonate of ammonia, and* 4 *of the carbonate of potassa,* and dissolve in 4 of water; distil with a gentle heat in a retort; ammonia is found in the water of the receiver, and bi-carbonate of potassa in the retort, without any loss of materials.[‡]

(*c.*) *By exposing potassa, or its carbonate, in the vats of the brewer, or of the distiller,* we can obtain the crystallized bi-carbonate.

2. PROPERTIES.

(*a.*) *Crystallizes in tables, or quadrilateral prisms,* and is terminated by pyramids.

(*b.*) *Taste, slightly alkaline, but not caustic; mild in the stomach,* not deliquescent.

(*c.*) *Sometimes efflorescent.*[§]—Sp. gr. 2.012.

(*d.*) *Soluble at* 60°, *in about* 4 *parts of cold water, and in about* 5 *at* 212°. The strongest permanent solution at common temperature, has the sp. gr. 1.54, and contains 48.81, of carbonate.

(*e.*) *Boiling hot water expels bubbles of gas,* amounting to $\frac{1}{16}$ of its weight. *A boiling heat is therefore sufficient partly to decompose the salt.*

(*f.*) *Decrepitates and melts with a gentle heat,* loses its water, and a red heat expels just half its carbonic acid, leaving it a pure carbonate.

3. PROPORTION OF PRINCIPLES.—It contains twice as much carbonic acid as the carbonate; proved by the quantity of gas given out from each by the action of acids.

---

[*] Henry, 10th Ed. Vol. 1, p. 544.

[†] To 1 lb. of sub-carbonate of potash, in solution, add 2 or 3 oz. of carbonate of ammonia, and distil.—*Dr. Hope.*

[‡] During the saturation of common pot or pearlash, with carbonic acid, silica is always deposited.

[§] Four. Vol. IV, p. 41.

Acid, 43.9,+ base, 47.1,+ water, 9.0=100.—2 prop. carbonic acid, 44+ 1 potassa, 48,+ 1 water, 9=101 for its equivalent.

4. Action of preceding bodies.

(*a.*) The action of sulphur and of the acids, has been already explained.

(*b.*) *Decomposed by baryta, strontia, and lime,* and an earthy carbonate is precipitated.

(*c.*) *Silica and alumina, by ignition, expel the acid,* and unite with the alkali, as before stated under the manufacture of glass.

(*d.*) In the humid way, decomposes the nitrate and muriate of baryta, and in the dry way, the sulphate. (See that salt.)

5. Uses of the carbonates of potassa.

Numerous in the arts.—See potassa.

In medicine, employed as an *antacid and lithontriptic,* of undoubted efficacy; the bi-carbonate in good crystals should be preferred; it is dissolved in water, or in any mild fluid. When the solution is swallowed, the gas is often disengaged by acid in the stomach, or by some mild vegetable acid, taken for the purpose.

The crystals are often taken, a tea-spoonful at once, or in doses of 15 to 20 grains, and they operate actively as a diuretic, especially if the solution is considerably diluted. The term super-carbonate, formerly applied to this salt, is incorrect. Dr. Coxe justly remarks, that there can be no super-carbonate, except when the solution is highly charged with carbonic acid gas, by pressure and cold.

The bi-carbonate is one of the most elegant of the antacid remedies; it should be in every family, being perfectly safe and useful in cases of disordered digestion. With the vegetable acids, especially the tartaric, or citric, it forms a fine effervescing mixture.

CARBONATE AND BI-CARBONATE OF SODA.

CARBONATE.

1. Natural History and Origin.

(*a.*) Obtained by incineration of marine plants, &c.*

(*b.*) In commerce, the impure soda, or carbonate of soda, is called barilla, or kelp; it contains, besides this salt, sulphate, muriate, and sulphuret of soda, sulphuret of lime, usually hydriodate of potassa, and much earthy and carbonaceous matter.

---

* As already mentioned under soda, it is obtained from the sal sola soda and kali, in Spain, the sal sola soda, and the salicornia herbacea, are most esteemed; from the fuci and other marine plants, in Scotland; from lakes and spontaneous efflorescence in Egypt; from veins in the mountains near Tripoli, and from the decomposition of common salt. It effloresces on damp walls, generally on such as consist in part of lime and sea sand, the carbonate of lime and the muriate of soda mutually decomposing each other.

2. Names.—*The Nitre of the scriptures is the carbonate of soda.*[*] Anciently *nitrum* or *natron*, and at Tripoli, called *Trona.*

3. Preparation.

(*a.*) *Carbonate of soda of the shops, may be purified by dissolving it in* ¼ or ⅕ of its weight of *water.*[†]

(*b.*) *Effloresced oarbonate of soda is the purest,* as it thus separates from other salts.

(*c.*) *The solution is to be evaporated at a low heat, and the crystals of muriate of soda* skimmed off, till they cease to be produced, and then the solution may be suffered to crystallize by cooling.[‡]

4. Properties.

(*a.*) *The crystals are decahedra,* composed of two quadrilateral pyramids, united at the bases, and truncated at their apices; the primary is an oblique rhombic prism.

(*b.*) *Taste is alkaline but not caustic;* turns blue vegetable colors green.

(*c.*) Specific gravity 1.3591.

(*d.*) *Soluble in 2 parts of water at* 60°, and in somewhat less than 1 part at 212°. As the solution cools it deposits crystals. The strongest permanent solution, at common temperature, has the specific gravity 1.26.

(*e.*) *The bi-carbonate of potassa is scarcely altered by the air; the carbonate deliquesces, but the carbonate of soda,* on account of its large quantity of water of crystallization, (62.69 per cent.) effloresces rapidly and falls into powder.

(*f.*) *By being again dissolved in water, it crystallizes anew.*

(*g.*) *Readily suffers the aqueous,* and by ignition, the real igneous *fusion.*

(*h.*) *By a very violent heat most of its carbonic acid is expelled,* but not the whole.

5. Proportion of its principles.

(*a.*) By the action of a known and a sufficient weight of sulphuric acid, the quantity of carbonic acid is determined, and this action joined with the effects of heat, has given the following for its composition. Acid 13.98, base 23.33, water 62.69=100.00, and omitting the water,

Acid, - -	41.23	or 1 proportion	=22
Soda, - - -	58.77	or 1 "	=32
	100.00		54

and the crystals of

---

[*] See p. 251, (Soda.)

[†] Four. Vol. IV, p. 51.

[‡] The calcined acetate, dissolved and filtered, and the bi-carbonate heated in the same manner, afford a pure carbonate.

Carbonate of soda,	37.5 or 1 proportion	=54
Water, - -	62.5 or 10 "	=90
	100.	144

(*b.*) 100 grains anhydrous carbonate neutralize 460 of sulphuric acid, density 1.141; therefore supposing no other alkali present, as 460 to the acid required to saturate 100 grains of any sample of carbonate of soda, : : 100 to the quantity of anhydrous carbonate.*

6. Action on preceding bodies.

(*a.*) All that was said under the preceding article is true of this, and need not be repeated.

(*b.*) *Potassa decomposes this salt and renders the soda caustic*, just as the alkaline earths act upon the carbonate of potassa.

(*c.*) Carbonate of soda, like carbonate of potassa, by double elective attraction, decomposes many salts, even sulphate of baryta, by ignition.

7. Uses.

(*a.*) *Very valuable in the arts;* in the manufacture of glass, especially of the finer kinds, which it renders more fusible; of hard soap; in dying; and as a detergent in washing and in bleaching; but for the two latter uses it must be rendered caustic.

(*b.*) *In soda water it is now extensively used as an antacid and lithontriptic, &c.* and as an agreeable beverage. The watery solution of the salt is supersaturated with carbonic acid. It is prepared in an iron bound barrel or a strong copper vessel lined with tin, furnished with means of internal agitation; the gas is injected by means of a forcing pump; four or five volumes of the gas are thus condensed into one of water. Proportion of alkali, two ounces to ten pounds of water, or from two and a half to three pounds, for a barrel.

REMARKS ON SODA WATER.

Having been concerned in the introduction of soda water, into this country,† and having been much conversant with its manufacture and use, I may be permitted to observe—

(*a.*) *That if properly prepared, soda water is a very valuable thing.*—To this end, the full proportion of soda should be dissolved in the water, and with the aid of cold, agitation and pressure, it should be made to absorb carbonic acid as much as possible. This will depend upon the strength of the machinery, and upon the well known law, that if, as is the case with the carbonic acid gas, water, at the common atmospheric pressure, absorbs an equal volume; with a double pressure it will absorb two volumes, with a pressure again doubled, the absorption will again be doubled, that is, it will be four times the first, and so on.

---

* Henry, Vol. I, p. 565, 10th ed.

† March, 1807.

(*b.*) *Water impregnated with carbonic acid merely, is erroneously called soda water;* it is a pleasant brisk acidulous drink, and to a degree useful, but it will not remove acidity; it will act feebly in correcting the alimentary canal, and it will have only partial activity as a diuretic and lithontriptic.

(*c.*) *If the water contains only a little carbonate of soda,* it will still fall far short of the qualities of genuine soda water.

(*d.*) *It is not sufficient to add the solution of the salt at the time,* and to draw the water impregnated with carbonic acid upon it; this will indeed be more useful than the water named at (*b*) &c. but it will be, comparatively vapid, because the alkali attracts away the free carbonic acid, which gives briskness to the water, and the saturation which ought to have been fully made in the machine, is very imperfectly made in the drinking glass.

(*e.*) *The genuine soda water, with the full charge of alkali and gas, is an excellent antacid, diuretic, lithontriptic and anti-dyspeptic remedy; but much that is called soda water, possesses these properties only in a very small degree.*

(*f.*) *Soda water may be used too freely.*—Large quantities of water may weaken the digestion, and produce injury also by the cold; and where the diuretic effect is needed, it is better to repeat the drinking at convenient intervals.

(*g.*) *Cordials and syrups mixed with the soda water,* greatly impair or destroy its salutary effects, and may lead to other bad results.

BI-CARBONATE OF SODA.

1. PREPARATION.

(*a.*) *The saturated solution* just described, or a similar solution impregnated to saturation in any other way, *will,* when gently evaporated without heat, *afford confused crystals of bi-carbonate.*

(*b.*) Or 100 parts of the solution of common carbonate, mixed with 14 of carbonate of ammonia, distilled, evaporated and crystallized, as in the case of carbonate of potassa, will produce the salt.

(*c.*) *Exposure of the carbonate, in a brewer's or distiller's vat,* to the action of carbonic acid gas, *will spontaneously effect the combination.*

2. PROPERTIES.

(*a.*) *Taste mild;* at 60° soluble in 9 or 10 parts of water.

(*b.*) *Gentle heat expels part of the gas* and it escapes in a vacuum.

(*c.*) *Affects the test colors,* as the sub-carbonate.

(*d.*) 100 grains, at low ignition, lose 37.4, and 62.6 remain of dry anhydrous carbonate.

(*e.*) Constitution—

carb. acid,	57.9	or 2 pro.	44
soda,	42.1	or 1 "	32
	100.		76 its equivalent.

If crystallized, 2 proportions of water, 18, will make the equivalent, 94.

The trona of Africa is said to be a sesqui-carbonate,* that is, intermediate between the carbonate and bi-carbonate, consisting of

Carbonic acid,	39.76	or 3 proportions =	66
Soda, - -	38.55	or 2 "	64
Water, - -	21.69	or 4 "	36
	100.		166 its equivalent.

3. Uses.—*An elegant antacid;* it is now prepared in the large way, and is perhaps preferable, on some accounts, to the bi-carbonate of potassa. It is taken freely; the dose mentioned in the pharmacopœias is two scruples a day, using the effloresced crystals, which will contain about twice as much alkali as the crystals. It may be taken in powder or in pills. It should be kept in families.

The effervescing draughts which are made with what are called soda powders are not soda water; the powders are put up in papers; the blue paper contains half a drachm of carbonate of soda, and the white twenty five grains of tartaric acid, which require half a pint of water; the effervescing drink is a mixture of tartrate of soda and carbonic acid, with perhaps some free alkali. The Seidlitz powders have two drachms of tartarized soda and two scruples of carbonate of soda in the white paper, and thirty five grains of tartaric acid in the blue; to a solution of the former in half a pint of water the latter is added. These preparations are however both useful and agreeable.†

CARBONATES OF AMMONIA.

1. Names, &c.—In the shops, *volatile salts or concrete, volatile alkali, sal cornu cervi,* or salt of hartshorn; *volatile salts,* is the name most familiar to the apothecary, (it is now called in chemistry, sesqui-carbonate.)

2. Preparation, *of the salt of the shops.*

(*a.*) *Obtained in the manufactories,* by distilling, in earthen or iron retorts—*bones, horns,* or other *firm animal substances.*‡

(*b.*) *In pharmacy, by heating dry chalk,* 1 *part, and dry muriate of ammonia,* 2 *parts,* in an earthen retort, or one of coated glass; the sublimed salt is condensed in a cold receiver.§

(*c.*) *Process of the apothecaries.*—Muriate of ammonia, 1 part, and carbonate of lime, 1½, are mingled, 100 cwt. or more at once;

---

* See Quart. Jour. VII. 298, and Henry, Vol. I, p. 566, 10th ed.

† Coxe. ‡ See Ammonia, p. 236.—10.

§ It will be seen, farther on, that the salt formed in this manner has different proportions from that which is prepared by mingling the gases in equal volumes; the latter is strictly the carbonate.

an iron pot with an earthen head, communicating with a cold receiver, usually a jug or bottle; (the olive oil bottles, after being cleansed, are commonly preferred;) the carbonate of ammonia, produced from repeated charges of the materials, accumulates by degrees to a thick crust, and the bottles are then broken to extract it. Sometimes lead receivers are employed, and then the crust is detached by repeated blows of a wooden hammer, applied to the outside.*

3. PROPERTIES, *of the salt of the shops.*

(*a.*) *The crystals are so minute as to be indistinct;* they are said to be octahedra with truncated apices.

(*b.*) *Volatile and odorous;* smell and taste are like those of pure ammonia, but weaker. The hartshorn smelling bottles, are lined with this salt, whose odor is reviving, stimulating, and refreshing.

(*c.*) *Has the usual alkaline action upon the test colors.*

(*d.*) Soluble at 60°, in less than 2 parts of cold water; and in one of hot water.

In boiling water volatilized, and also perhaps, decomposed, and exhaled in gas and vapor, with brisk ebullition and a strong ammoniacal odor.

(*e.*) The hot solution by rapid cooling, crystallizes.†

(*f.*) *Not altered by the air, but wastes rapidly away.*

(*g.*) *Evaporates on a hot iron*, without melting, being more vaporizable than fusible. Smelling bottles are easily made by heating a portion of this salt in a flask, whose neck is prolonged by a tube, covered by an inverted empty vial, in which the sublimed salt will be condensed and form a crust or lining.

4. ACTION OF THE PRECEDING BODIES.

(*a.*) *Nearly the same that has been stated with respect to the preceding alkalies;* they and the alkaline earths attract its acid and liberate the ammonia, while the acids attract the ammonia and liberate the acid gas with effervescence; if the acid is a fuming one, there is a white cloud.

(*b.*) No action on silica, alumina, or zirconia; but dissolves glucina readily.‡

(*c.*) *By double affinity, decomposes various salts which ammonia alone will not affect;* particularly the barytic, strontitic, and calcareous, but the carbonic acid often holds suspended the earthy carbonate, so that it does not precipitate till heat is applied, sometimes even to ebullition.

---

* Dr Murray's Lecture on Materia Medica, March 26, 1806.

† Bergman. Four. IV. 74.

‡ It separates glucina from the other earths contained in the beryl and emerald; and by evaporation, it deposits the glucina. Four. IV. 75, and this work, p. 298.

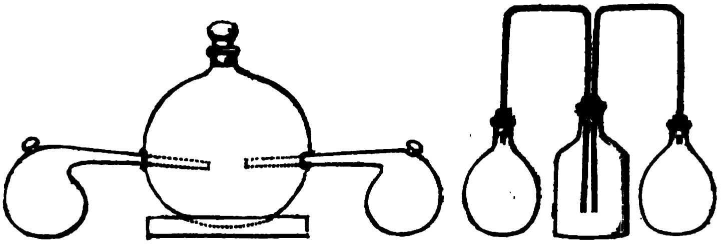
SESQUI*-CARBONATE.

This name, as already implied, has been given to the salt just described, and which is obtained by subliming 1 part of muriate of ammonia, and 1½ of dry carbonate of lime; if no loss were sustained, it should contain equal quantities of carbonic acid, ammonia, and water; but both ammonia and water are wasted by the heat, and it in fact consists of about 55 acid, 30 base, and 15 water, corresponding very nearly with the constitution, of acid, 3 proportions, =66, base, 2 =34, water, 2=18=118, for its equivalent. This is Dr. Henry's view, and if correct, there seems to be no occasion, in this case, for a name implying half a proportion; for 66 is obviously a multiple of 22, as 34 is of 17.†

CARBONATE OF AMMONIA.

1. **Preparation.**—There is but one mode of forming the carbonate containing one equivalent of each of the principles, and that is by mingling *carbonic acid gas* 1 *volume, and ammonia* 2, over mercury; or in a dry bottle, the gases coming from different vessels; the solid carbonate is precipitated, and crystallizes in plumose rays on the interior of the vessels.

Either of the arrangements represented by the annexed figures will answer very well for this experiment; muriate of ammonia and lime being in one of the retorts or flasks, and marble powder and diluted sulphuric acid in the other. A mild heat is applied to the vessel containing the materials for affording ammonia, and the middle vessel receives the condensed gases.



2. **Composition.**—

Acid,	56.20,	1 proportion,	22
Alkali,	43.80,	1 "	17
	100.00		39, its equivalent.

This salt is unknown in the shops.

---

* *Sesqui*—Latin, one and a half.

† Dr. Thomson, who introduced the term sesqui, to provide for cases, where there appears to be half an equivalent, admits fractions of atoms as a provisional mode of expression, although, as he distinctly explains, from the very nature of atoms, they do not admit of fractions.—First Principles, Vol. I, p. 82.

BI-CARBONATE.

1. **Preparation, &c.**

(*a.*) *Through a solution of the carbonate*, in Nooth's or other convenient machine, *pass a stream of carbonic acid gas* to saturation.

(*b.*) Gentle evaporation gives small six sided prisms, inodorous and nearly tasteless.

(*c.*) A salt extremely similar, appears to be formed, when common carbonate of ammonia of the shops, is simply exposed in powder, to the air; it loses sometimes nearly half its weight, in a single night; the ammonia and perhaps the water, are more wasted than the carbonic acid, and the proportion of the latter is doubled. We may often observe that the volatile salts of the shops, when exposed to the air, become nearly inodorous and their taste less active.

The composition, exclusive of water, is,

Carb. acid,	71.81,	2 proportions, - - -	44
Ammonia,	28.19,	1 " - - -	17
	100.00	Its equivalent	61

" By varying the proportions of the ingredients and the regulation of the heat, it is possible to obtain a bi-carbonate at once, by sublimation.*

Remarks.—The carbonate of ammonia commonly used in medicine and chemistry, is that of the shops. In medicine, it is a valuable remedy; stimulating, diuretic, antacid, anti-poisonous, &c. The smelling bottles that have not been exposed much to the air, exhale an odor that is highly stimulating; but by careless keeping or frequent opening, they often lose their activity. As a reagent, the carbonate of ammonia is very valuable in chemistry; it is the most convenient application, for the removal of acid stains from dark clothes. It should be used in solution.

This is an elegant salt, composed entirely of condensed gases; its elements are, for the acid, carbon and oxygen; for the ammonia, hydrogen and nitrogen.† It is a striking example of the production of new properties by chemical combination.

EARTHY CARBONATES—CARBONATE OF LIME.

1. **Names.**—*Chalk, limestone, marble, calcareous spar, stalactite, &c.*—The natural carbonate of lime, is in these and other forms, most extensively diffused, and contributes to many purposes of ornament and utility.

---

* Ann. of Philos. N. S. III. 110, and Henry, Vol. I, p. 419.

† Thus arranged—carbon 6+2 proportion of oxygen, 16 = 22 carb. acid; nitrogen, 14+3 prop. hyd. = 17 ammonia, and there are two propor. of carb. acid, 44+1 of ammonia, 17 = 61, as above.

2. **General characters of the carbonates of lime.**

(*a.*) Do not scintillate, if pure.

(*b.*) Insoluble in pure water.

(*c.*) Effervesce with acids generally, but unequally.*

(*d.*) Become quick lime by a strong heat.

(*e.*) Sp. gr. under 3., generally not over 2.7.

(*f.*) Every variety of aggregation, from compact, and even earthy, to perfect crystals, which are much diversified in form.

(*g.*) The crystals of all pure calcareous carbonates, between 600 and 700 in number, have a rhomboidal nucleus, whose faces are inclined at angles of 75° 55′ and 105° 5′.

3. **Chemical properties.**

(*a.*) *Caloric.—Native crystallized carbonate decrepitates with heat. Ignition separates the carbonic acid gas,*† and the watery vapor, and caustic lime remains. By strong ignition, it loses .44 or .45 in weight, about .44 of which is acid.

(*b.*) *That the causticity of lime is owing to the loss of carbonic acid*, was discovered by Dr. Black in 1756.

(*c.*) This gas in contact with caustic lime, renders it again mild and effervescent,‡ and restores the weight lost by the furnace.

(*d.*) Not affected by air nor water.

(*e.*) *Soluble in liquid carbonic acid.*—If saturated with the acid, water dissolves $\frac{1}{1500}$ of carbonate of lime. Lime water is a most sensible test of carbonic acid, producing a milky appearance, and carbonate of lime precipitates; but if more carbonated water be added, the precipitate is redissolved, and the fluid becomes again transparent.

(*f.*) If the excess of carbonic acid be saturated by more lime water, or by ammonia, the carbonate of lime is again precipitated. It is precipitated also by boiling, and by air pump exhaustion.

(*g.*) The formation of stalactites, and stalagmites, and calcareous incrustations of various forms, in caverns and veins, and of calcareous petrifactions, and the precipitation of the carbonate in a crystalline or sub-crystalline form, as the water and gas evaporate, depend upon the solution of limestone, by liquid carbonic acid. In limestone countries, carbonate of lime is dissolved in the waters, usually by the agency of carbonic acid, and appears in the domestic utensils; it is deposited by boiling, the gas being thus expelled.*

---

* Some carbonates, especially of earths, require to be finely pulverized.

† Sir James Hall, by some very ingenious experiments, on carbonate of lime, as to the effects of pressure in counteracting those of heat, succeeded in melting that substance, and causing it to crystallize again, without losing its carbonic acid. Edin. Trans. Vol. VI. part I. Nicholson's Jour. Vol. XIII, XIV.

Mr. Bucholz also melted the carbonate of lime by the sudden application of a violent heat, without compression.—Nicholson's Jour. XVII, and Henry, Vol. I, p. 588, 10th Ed.

‡ The lime should be moist, or in the state of cream of lime, or least of the hydrate, as the gas is not readily absorbed by the dry earth.

4. ACTION OF PRECEDING BODIES.

(*a.*) *Decomposed by acids, with effervescence.*†

(*b.*) *No heat is evolved by acids acting on a calcareous carbonate,* while with quick lime, there is great heat, especially with sulphuric acid. The same is true of potassa, soda, and magnesia, when compared with their carbonates. In the cases in which gas is evolved, the heat is absorbed to form it, and thus becomes latent, and insensible; the opposite will therefore be true of the caustic substances.

5. ESTIMATION OF PROPORTIONS.

(*a.*) This subject has occupied the attention of many distinguished chemists. The analyses of Dr. Wollaston, Prof. Berzelius, and Dr. Ure coincide so nearly in the proportions of 44 acid and 56 lime, that these numbers have been adopted by Dr. Henry, and they correspond with one proportion of acid, 22, and 1 of lime, 28=50 for the equivalent.

(*b.*) *To ascertain the proportion of carbonate of lime in any marl or limestone.*‡—Effervescence with acids is generally regarded as a proof of the presence of a carbonate of lime. There are, however, carbonates of other substances, and there are other combined gases, besides carbonic acid, that may be disengaged with effervescence, by acids; but these cases are so rare, and the other so common, that there is little danger of mistake, especially when the peculiar characters of the other carbonates are taken into view.

(*c.*) *We must not be deceived by the common air lodged in the pores of dry earthy bodies;* when the acid is added, this air is expelled by hydrostatic pressure, and exhibits a false effervescence. The matter should be first immersed in water, and the air thus expelled, and then the acid may be added.

(*d.*) *For an accurate result,* place in one scale, in a flask 100 grs. of the substance, and in a separate vessel, 100 of muriatic acid, mixed with 200 of water, and put a counterpoise to the whole in the opposite scale. Add the diluted acid, by degrees, till effervescence has ceased, and then weigh the residuum accurately. The loss of weight is the carbonic acid; therefore, 44 : 100 : : the weight lost to the proportion of carbonate of lime,§ granting that there is no other carbon-

---

* The temporarily injurious effects of such waters upon the health of strangers are well known.

† Even vinegar will, in a degree, produce that effect.

‡ See Ure's Dict. 2d Ed. p. 297.

§ Carbonate of magnesia may be present.

From 100 grains of carbonate of lime, 80 or 90 cubic inches of gas are obtained. It is a rich marl, that has 1-4 of its weight of carbonate of lime, and sometimes marls do not contain more than 1-20th. In trying marls, you may reckon 2 1-2 grains of ate present; a complete solution indicates a pure carbonate, probably of lime, or of lime and magnesia.*

(*e.*) *Expel the gas by a red heat*, and compare the weight lost in this trial and in the other experiment; the loss may be a little greater on account of water. We must also try the residuum with an acid to see whether it effervesces, and whether it contains magnesia.†

USES.—As an antacid; in chalk, as a crayon; in marble and other solid forms, as a building stone, valuable both for firmness and beauty; to afford lime by burning, and carbonic acid for the chemists and manufacturers; as a manure, both in the form of lime and of carbonate of lime—the burning appears to be of no use, except to diminish weight and cohesion, so that it may be scattered in powder on the land, where, if it be quick lime, it reabsorbs carbonic acid and water, and becomes again carbonate of lime.

CARBONATE OF BARYTA.

1. DISCOVERY.

(*a.*) By SCHEELE and BERGMAN, but Dr. WITHERING,‡ first found the native mineral in 1783.

2. PREPARATION.—For demonstrations, *the native carbonate of baryta may be used*, but for instruction, a number of processes may be mentioned.

(*a.*) By *passing* a current of *carbonic acid* gas *through* a solution of pure *baryta.*

(*b.*) *By exposing the latter to the air*, when a pellicle of carbonate of baryta forms on the surface, and being removed, another succeeds, and so on, till the baryta is all precipitated.

(*c.*) *By mixing watery solutions of carbonic acid and baryta.*

(*d.*) *By decomposing*, by fire, *the sulphate* of baryta, 1 part; *by the carbonate of a fixed alkali*, 2 or 3 parts.

(*e.*) *By any alkaline carbonate, added to the nitrate or muriate of baryta.*

(*f.*) By blowing air from the lungs through barytic water.

---

lime stone, or 1 1-2 grains of lime for every grain the marl loses by the experiment of expelling the air. Vinegar is not sufficiently strong, and it froths and becomes clammy, and remains for several days without permitting all the gas to escape.—*Black's Lect. Vol. II, p.* 120.

* The residuum, if any, should be dried, and weighed, and this may correct the former conclusion.

† If magnesia be present, it will be detected by sulphuric acid, which will form a bitter soluble and crystallizable sulphate of magnesia, or Epsom salt. Such a marl or limestone would be injurious, if applied in agriculture, in quantities as large as when a pure calcareous earth is employed; much less of it answers the purpose.—Nicholson's Jour. 4to. Vol. III, p. 440, Phil. Trans. 1799, part II, p. 305, and Bakewell's Geology.

‡ Called after him, *Witherite.*

(*g.*) ***By adding carbonate of soda to the hydroguretted sulphuret of baryta***, formed by decomposing the native* sulphuret, by ignition with charcoal, as already described.

3. **Properties.**

(*a.*) The artificial carbonate is a white powder whose specific gravity is 3.763; that of the native, 4.3 or 4.4.

(*b.*) *Caloric.*—Dr. Hope often expelled the carbonic acid by the well managed heat of a smith's forge,† and obtained the caustic earth.

(*c.*) Fusible on charcoal, losing at the same time, some of the carbonic acid.

(*d.*) Mix‡ fine powder, of either artificial or native carbonate of baryta, with about its volume of lampblack, and add lamp oil, until the mass can be rolled into a ball; place it in a black lead crucible, surrounding it with lampblack or charcoal powder, and lute on a cover; heat the whole in a good forge or wind furnace for an hour. The ball still retaining its form, may now be taken out, and boiling hot water added; it will slack powerfully, and when cold, will shoot into beautiful crystals.

(*e.*) *Soluble in* 4300 *parts of water at* 60°, in 2300 at 212°; water impregnated with carbonic acid, dissolves with some facility that which has been recently precipitated, and takes up $\frac{1}{830}$; it is precipitated and redissolved exactly in the same modes that were mentioned under carbonate of lime.

(*f.*) *Tasteless—no effect on test colors.*

(*g.*) *A violent poison*, not known in common life, except in those places where it is found native.

(*h.*) *Decomposed by most of the acids with effervescence*, producing salts; there are some peculiar circumstances which will be mentioned under the other barytic combinations.

---

* The native carbonate is found in Cumberland, (England,) at Alston Moor; in Lancashire, at Anglezark, near Chorley; and in other parts of England; in Scotland, and in Sweden. It was announced, (Am. Jour. Vol. II,) as existing near Lexington, Kentucky, but this has not been confirmed. It is commonly found in metallic veins along with sulphate of baryta, and various metallic substances. Its sp. gr. is 4.33 or 4.4, whence it appears that it is much heavier than the artificial; it is a little harder than carbonate of lime, but softer than the fluate.

† Dr. Priestley, by steam, passed over the ignited artificial carbonate, reduced it to the state of baryta; in this case, the attraction of the water for the base, aids the decomposition.

‡ In this process, the carbonic acid is not only expelled, but in part decomposed by the carbon, which, with one proportion of the oxygen, produces carbonic oxide. The process I find to be constantly successful, and it is very eligible when we wish to obtain either a solution or crystals of baryta. We may begin with the sulphate, decompose it by ignition with charcoal; form the sulphuretted hydro-sulphuret; decompose this by an alkaline carbonate, and thus obtain the carbonate of baryta for this experiment.

4. **Composition.**—Carbonic acid, 22, baryta, 78=100, its equivalent.

5. **Miscellaneous.**—Used for a long time in Lancashire, to kill rats. With 40 grs. Mr. Watt killed a small dog; even 15 grains will produce that effect. It appears that domestic fowls are sometimes killed by swallowing fragments of the native spar, and that even cows, by licking it, suffer the same fate.*

According to Dr. Hope, there is very little or no difference between lime and baryta in their attraction for carbonic acid; lime water does not decompose carbonate of baryta, nor the contrary, and when carbonic acid is added to a mixture of lime water and barytic water, carbonates of both those substances are precipitated.

6. **Uses.**—Mr. Parkes† states, that great quantities of the carbonate of baryta were formerly exported clandestinely from England to Germany, where it is supposed it was used in the manufacture of porcelain; it was sold for five dollars a ton.

Carbonate of baryta is a rather rare production in nature. If it were more common, it might be employed with much advantage in some of the arts—as, to afford baryta, which, in building, would form a stronger cement than lime, and to decompose some of the compound salts. Pure baryta in solution, will separate the carbonic acid entirely from a solution of carbonate of potassa or soda, and leave the alkali caustic.

CARBONATE OF STRONTIA.

1. **Discovery.**—*At first confounded with the preceding;* the difference suspected by Dr. Crawford, was proved by Dr. Hope.‡

2. **Preparation.**

(*a.*) *By adding liquid carbonic acid to a solution of strontia,* the precipitate, is again soluble in an excess of carbonic acid, and is thrown down by more of the earth, and so on in the same way as that mentioned under the carbonates of lime and of baryta.

(*b.*) *By the various methods already indicated,* for the formation of a carbonate of baryta, strontia being of course substituted.

The native carbonate, although a very rare production, is commonly used in laboratories; it is found at Strontian, in Argyleshire, and at Lead Hills, in Scotland, &c.

3. **Properties.**

(*a.*) *The native carbonate has a fibrous and columnar texture,* and the cavities are usually lined with crystals, which are generally translucent; the color is green or greenish; sp. gr. 3.55 or 3.66; does not fire with steel; it is softer than the fluate, although harder than the carbonate of lime; soluble in 1536 parts of boiling water. It is insipid.

---

* Parkes. † Essays, Vol. I, p. 327. ‡ Vide Edin. Trans. 1793.

(*b.*) *Fusible at 226°, W. into a glass;* losing 5 or 6 per cent. of its carbonic acid; in a black lead crucible, and especially if mixed with charcoal and oil, the carbonic acid is wholly expelled, and the caustic earth remains; this may be done in a smith's forge; *in a strong fire, it fluxes a Hessian crucible and produces a glass resembling chrysolite.*

(*c.*) *Air does not affect it.*

(*d.*) *Decomposed by the acids*, with effervescence.

4. Composition.—According to the analysis of Stromeyer,* the artificial carbonate contains no water, and has very nearly .30 carbonic acid, and .70 strontia.

The equivalent of strontia, is 52, that of carbonic acid, 22, and as 22 : 52 : : 70 : 30, very nearly; so that the theoretical constitution agrees almost with the results of analysis.

5. Miscellaneous.

(*a.*) *Strontia takes the carbonic acid from all the alkalies;* its carbonate, with the aid of heat, is decomposed by baryta only;† still it is uncertain which of the alkaline earths has the stronger attraction for carbonic acid.‡ Distinguished from carbonate of baryta, by *an inferior sp. gr.* by the fact that *its salts yield their acids to baryta,* and that *it is not poisonous;* animals may take it with impunity; *its nitrate tinges the flame of a candle red;* that of baryta tinges it yellow; under the compound blowpipe, *all its varieties give a red flame,* and all those of baryta a yellow one. It has never been introduced into medicine, and is of no use except to chemists.

CARBONATE OF MAGNESIA.

1. History.—Long known, but not well understood till Dr. Black gave its true theory, as well as that of lime and the alkalies.§

2. Preparation.

(*a.*) *By slowly dissolving pure magnesia in liquid carbonic acid.*||

---

* Ann. de Chim. et de Phys. III, 396.

† Four. IV, 22. ‡ Dr. Hope.

§ Every student should read Dr. Black's own account of the gradual developement of this curious and instructive subject—namely, the relation of carbonic acid to the alkaline substances; it is a fine example of inductive reasoning, and has contributed more than any other thing to the progress of pneumatic chemistry. See Robison's Black's Lectures.

|| A native carbonate of magnesia has been found in the East Indies, and analyzed by Dr. Henry, Ann. of Philos. N. S. I, 252. Native carbonates have been found at Hoboken, near New York, Am. Jour. Vol. I. Calcined or pure magnesia, unlike the alkalies and the other alkaline earths, does not absorb much carbonic acid from the air, and consequently, it acquires little weight except from the absorption of water, which makes it a hydrate, and it afterwards acquires some carbonic acid.

(*b.*) ***By decomposing the sulphate of magnesia, by the carbonate of an alkali.***—The sulphate, 1 part, dissolved in 2 parts of pure water; and 1 part of pearl ashes, dissolved in 4 or 5 parts of water.*

Dr. Black's process.—Mix the two solutions by violent agitation, and let the mixture merely boil; add four parts of water, at 212°, and again agitate briskly. After repose, the magnesia subsides very slowly, in the form of an impalpable powder; next decant, and to remove the sulphate of potassa, edulcorate ten or twelve times with abundance of cold water.†

Lastly, the magnesia must be gently pressed on a clean linen cloth, for the filtering papers will not do, on account of the jelly-like consistency, which magnesia, when wet, assumes. It is divided into cubical pieces, by cutting it before it is quite dry, with a square frame; but when dried, it becomes an exceedingly light and spongy powder, and this extreme lightness is one of the best marks of its goodness.‡

In decomposing the sulphate of magnesia with the carbonate of potassa,§ or other alkaline carbonates; the precipitate does not always immediately appear, ***because the carbonate of magnesia is held in solution by the carbonic acid,*** and is precipitated as fast as this is evaporated, spontaneously or by heat, or by the air pump.

3. PROPERTIES.

(*a.*) ***A mild, white, friable, spongy substance,*** very light, but usually feebly cohering in a sort of cake, generally so light on account of its porosity, as to float on water; but it eventually absorbs so much as to sink.

(*b.*) *Solubility in water;* 1 part of carbonate of magnesia, in 2493 parts of cold, and 9000 of hot water, presenting a singular anomaly, which is doubtless owing to the additional elasticity given to the carbonic acid by the heat, and the hotter the water is, the more carbonic acid is expelled, and the more insoluble the carbonate becomes.

(*c.*) This solution changes the color of purple cabbage or mallows, to green.

(*d.*) *Suffers no change from the air.*

---

* These are clarified by subsidence and decantation, and the Epsom salt, by agitating in it the white of an egg, when the solution is just warm enough to produce coagulation.

† Hot water occasions a much longer suspension of the magnesia.

‡ The theory which Dr. Black was establishing concerning the combined state of carbonic acid, made him peculiarly nice in the preparation of magnesia. Black, II, 57, and Dr. Murray's private instructions.

§ As the common pearl ashes often contains silica, the magnesia may be examined by sulphuric acid, in which, if pure, it is entirely soluble, while the silica will be left behind. If the carbonate of ammonia or of soda, were employed, there would be no danger of the presence of silica, and the bi-carbonate of potassa would not contain it.

(*e*.) *Decomposed by all the acids*, with effervescence.

(*f*.) *Also by all the alkaline bases*, forming carbonates; and in turn *decomposes their salts*, by double attraction.

(*g*.) Lime water and carbonate of magnesia produce a mixed precipitate of the two carbonates.

4. Composition.—According to Bucholz, if precipitated with heat, it contains magnesia 42, carbonic acid 35, water 23; if without, magnesia 33, carbonic acid 32, water 35. Mr. Dalton states it at magnesia 43, carbonic acid 40, water 17. Berzelius thinks that it is a compound of carbonate of magnesia, 3 proportions, with one of what is called quadro-hydrate of the same earth. Dr. Henry inclines to the same opinion, and states the composition thus;

3 equivalents of carbonate,	$42 \times 3 = 126$	69.2
1 do. quadro-hydrate,	$20 + 36 = 56$	30.8
Its equivalent,	182	100.0

Or of magnesia in the carbonate, - -	32.93	43.93
Do. in the hydrate, - - -	11.00	
Carbonic acid, - - - - - - -		36.32
Water, - - - - - - - - -		19.75
		100.00

Berzelius found the common magnesia of the shops, after being thoroughly washed in boiling hot water, to be composed of magnesia 44.58, carbonic acid 35.70, water 19.72=100.00.

CRYSTALLIZED CARBONATE OF MAGNESIA.

1. Process.—By diffusing magnesia in water, and passing a current of carbonic acid gas through it to saturation.

2. Properties.

(*a*.) *Much more soluble than the carbonate*, requiring only 48 parts of cold water, and water impregnated with carbonic acid takes up 13 grains to the ounce.

(*b*.) *When the solution is heated*, although transparent before, *it becomes turbid*, and again resumes its transparency on becoming cold.[†]

(*c*.) *It crystallizes, in transparent hexagonal prisms*, terminated by a hexagonal plane; partly in groups and partly solitary; length about 6 lines, and breadth 2.

(*d*.) *Effloresces in the air, and decrepitates in the fire;* it loses about .75 of its weight, while the common carbonate loses only .50.

---

[*] Thomson's First Principles, Vol. II, p. 303, and Henry, 10th ed. Vol. I, p. 617.

[†] The heat must be discontinued just at the point where the solution becomes turbid, or the carbonic acid will be driven off. The reason of this turbidness is supposed to be the elasticity of the gas, *tending* to escape, and thereby *beginning* to let go its hold on the magnesia.—*Dr. Hope, Note Book.*

(*e.*) During the disengagement of the gas, the powder seems as if boiling, and is said to emit, towards the end, a bluish phosphoric light.[*]

Remark.—The above described salt has been regarded as a bi-carbonate, but Dr. Henry is of opinion, from his own analysis and from that of Berzelius, that it is a hydrated carbonate and that its composition is

1	equivalent of	magnesia, - -	20	28.60
1	do.	carbonic acid, - - -	22	32.
3	do.	water, - - - -	27	39.40
		Its equivalent	69	100.00

It appears that, although the anhydrous carbonate has been found native, (see note p. 392,) it has not yet been formed by art.

Berzelius has formed a carbonate of magnesia and potassa, by mingling bi-carbonate of potassa and muriate of magnesia. It seems to be of little importance.[†]

3. Miscellaneous.—*In the arts*, the carbonate of magnesia is *prepared from the bittern of the salt pans*, remaining from the crystallization of common salt, which contains much muriate and sulphate of magnesia. Carbonate of either of the alkalies, by double exchange, affords carbonate of magnesia, whose precipitation is hastened by boiling.

4. Uses.—*As an antacid and cathartic.* (See magnesia, p. 273.) On account of the flatulency sometimes produced by the carbonate of magnesia, calcined magnesia is used. Dr. Black says that it is liable to contain a portion of quick lime, derived from the sulphate of lime of the bittern. No other earth has cathartic powers; most of the rest are austere and astringent, particularly lime.

CARBONIC OR CARBONOUS OXIDE.

1. History.—*Discovered by Dr. Priestley;* who obtained it from dry metallic oxides with dry charcoal, and thought it was, at least in part, hydrogen, or that hydrogen entered into its composition; it therefore revived, for a season, the once favorite notion of a phlogistic[‡] principle in the metals, charcoal, &c. and an animated con-

---

[*] Four. IV. 67.

[†] Edin. Phil. Jour. II. 67, and Henry, I. 619.

[‡] I happened to be in Philadelphia, as a pupil of Dr. Woodhouse, in the winter of 1802–3, when Dr. Priestley, who, as is well known, passed the latter years of his life in Pennsylvania, came in person, to the laboratory of Dr. Woodhouse, who was himself a disciple of Lavoisier, and who performed various experiments on this topic, at that time keenly controverted. It was the last effort to sustain the doctrine of phlogiston, and to produce from metals and inflammables a real substance, to which it was supposed that the name of phlogiston could be applied. Hydrogen had been before called phlogiston, but it was impossible to prove its existence in all inflammable bodies and metals, (unless the discovery of this gas should establish it,) and it was distinctly proved that it forms water by its combustion. Indeed Dr. Priestley was one of the first to perform that interesting experiment, but he did not eventually admit the conclusion.

troversy respecting it was for some time maintained, but its true nature was soon pointed out, by the late Mr. Cruickshanks, of Woolwich, England;* Clement and Desormes† completed the demonstration, and the refutation of the ideas of the associated Dutch chemists and others, who took it for a variety of carburetted hydrogen gas.‡

2. **Preparation.**—All the processes mentioned below, are instructive. They all shew, (that under (*g*) excepted,) the formation of an oxide of carbon, either by the combination of 1 equivalent of oxygen with 1 of carbon, or by the removal of 1 equivalent of oxygen from carbonic acid, leaving 1 of carbon and 1 of oxygen in combination. To the former belong the processes (*a*) (*e*), and (*f.*) to the latter (*b*), (*c*), and (*d*) ; (*g*) is peculiar.

(*a.*) *Heat white oxide of zinc with ⅛ of charcoal powder or iron filings;*

(*b.*) Or iron filings with an equal weight of chalk, previously heated moderately red.

(*c.*) Or dry carbonate of lime or of *baryta*§ *with ½ charcoal powder, previously ignited;* or *heat the same carbonates with ¼ or ⅛ of dry iron filings or metallic zinc.*

(*d.*) By passing carbonic acid over charcoal or iron filings, ignited in an earthen or perhaps iron tube.‖

(*e.*) Heat equal parts of the scales of iron with dried charcoal powder.

(*f.*) Manganese, after ceasing to give oxygen by heat alone, mixed with an equal weight of charcoal, previously ignited.¶

(*g.*) Still another process has been introduced, *by mixing salt of sorrel* 1 *part* (*bin-oxalate of potash*) *with* 5 *or* 6 *of sulphuric acid,* and heating the mixture to ebullition in a retort; decomposition of the oxalic acid ensues, and carbonic acid and carbonic oxide are evolved in equal measures; the former is easily absorbed by a caustic alkali or by lime water, and leaves the latter pure. The sulphuric acid is not decomposed; it remains limpid, and operates by uniting

---

[*] Nich. Jour. 4to, Vol. V. [†] Ann. de Chim. Vol. XXXIX.

[‡] Ann. de Chim. XXXIX, 26, and XLIII.

[§] The dry carbonate of baryta and dry iron filings give the purest gas, and nearly free from carbonic acid. The process with oxide of zinc and iron filings, is one of the best, and affords abundance of gas which is easily purified by washing it with caustic alkali or lime water.

[‖] See Nich. Jour. Vol. II, p. 116, for Baruel's apparatus.

[¶] Any carbonate, that will sustain ignition, without decomposition, will give carbonic oxide, if heated with half its weight of iron filings or charcoal; iron is of course, oxidized by the oxygen withdrawn from the carbonic acid which undergoes decomposition, giving up just half its oxygen; and charcoal is turned into carbonic oxide by the same process. The carbonates of strontia, soda, potassa and lithia, may be employed in addition to those that have been named, and the oxide of lead and copper may be used with charcoal, as well as the oxide of zinc or iron.

with the alkali of the salt and with the water of the oxalic acid, which being thus left at liberty, is decomposed as above.[*]

3. Properties.

(a.) *Smell offensive; colorless;* sp. gr. 972, common air being 1000. 100 cubic inches weigh 29.65 grains, at medium temperature and pressure; having the same weight as nitrogen.

(b.) *Does not support combustion;* a candle will not burn in it. *Inflammable, burning with a blue flame;* it takes fire at a low temperature, and an iron wire, at dull redness, kindles it; while the hydrogen gases require a full ignition or a white heat.

(c.) *It must be washed with lime water, or passed through milk of lime or caustic alkali,* as it always comes over with carbonic acid gas.

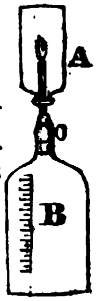
(d.) *Burn,* in a bottle of air, *a jet of this gas,* issuing from a jar with a stop cock, *and it will form carbonic acid.*[†]

(e.) Mixed with common air, it burns more rapidly, but does not explode, except in a few proportions, as 3 of the oxide gas to 1 of air.

(f.) *With oxygen gas 100 volumes and this gas about 200, it explodes by electricity, and the product is 200 of carbonic acid;* the two gases being mixed in the above proportions, when a candle is brought to the mouth of the vessel, burn rapidly, with a whistling noise, but scarcely explode.

(g.) Fire a jet of it and burn it in a tube, when it will produce feeble musical tones; and if burnt in a bottle of oxygen gas, over lime water, no water is formed but carbonic acid is produced.

(h.) It is well to burn and *explode* some *hydrogen,* and also varieties of *carburetted hydrogen, for comparison* with this gas, when it will be seen to be very different; it is less combustible, burns with a different flame and *produces carbonic acid only, without water,* while the former produces water only, and the latter both water and carbonic acid. The formation of water in this experiment, is owing to the hydrogen, and that of carbonic acid to the carbon contained in the gas.



[*] Edin. Jour. of Sci. No. xii, p. 350. Turner and Dumas.

[†] The carburetted hydrogen gases require iron in actual combustion, or the flame of some burning body, in order to set them on fire.

[‡] When this gas is burned in a bottle of common air, by means of a jar with a stop cock and tube, as in the annexed figure, no water is formed; but it is otherwise when hydrogen is burned.

A. Jar of common air.

B. Jar with a stop cock and tube, containing the gas.

(*i.*) *It is immediately fatal to animal life;* a bird put into it is not withdrawn alive.

(*j.*) *It produces giddiness and fainting in the human subject, even when mixed with common air.* Sir H. Davy was so daring as to take three inspirations of it, mixed with ¼ of common air, and it had nearly proved fatal; apoplectic symptoms were induced in Mr. Webster, who fell senseless, but was restored by inhaling oxygen gas.[*]

(*k.*) *But little soluble in water;* about 1 volume to 50.

(*l.*) *Not absorbed by caustic alkalies*, nor by lime water.

(*m.*) *Not altered by electricity.*

(*n.*) *Passed in equal volume with hydrogen, through an ignited tube, it is decomposed*, water is formed and charcoal thrown down, lining the tube.

(*o.*) *Potassium and sodium*, heated in it, *decompose it*, and precipitate the charcoal.

4. COMPOSITION.

(*a.*) 43 carbon, 57 oxygen, (Gay Lussac;) or 55.72 oxygen and 44.28 charcoal, (Berzelius.)[†] Carbonic acid is composed of 1 volume of gaseous carbon and 1 of oxygen condensed into 1 volume. This gas is composed of 1 volume of gaseous carbon and half a volume of oxygen, condensed into 1 volume; or of 1 equivalent of carbon =6+1 of oxygen[‡] =8=14, for its equivalent. *As it contains* just the same quantity of carbon as carbonic acid, occupies *the* same volume, and has only half as much oxygen, therefore, if from the specific gravity of carbonic acid, which is 1.527, we take 0.555, which is half the sp. gr. of oxygen, we have 0.972, the number stated under 3 (*a*), which corresponds with the results of experiment.

(*b.*) The discovery of the singular agencies of spongy platinum, has brought to light some new facts respecting oxide of carbon. Carbonic oxide, with more than half its volume of oxygen, in contact with spongy platinum, over mercury, begins to be converted into carbonic acid, at a temperature from 300° to 310° Fahr. and at a few degrees higher is acidified in a few minutes; at a common temperature there is little action.

(*c.*) Hydrogen and oxygen gases, in explosive proportions, mixed with an equal volume of carbonic oxide, do not detonate, when spongy platinum is added, but water and carbonic acid are slowly formed; if the proportion of the explosive mixture be larger, the metallic sponge always causes detonation.[§]

---

[*] Phil. Mag. V. 43. Ure, 2d ed. 299.

[†] And Clement and Desormes, nearly the same as Berzelius.

[‡] As half a volume of oxygen represents an equivalent.

[§] Phil. Trans. 1824, p. 271, quoted by Dr. Henry, Vol. I, p. 355, 10th ed.

Remark.—Frequently the oxide of carbon is produced at the same time with carbonic acid. The pale blue flame which arises from burning charcoal, especially when the fire is nearly burnt out, appears to be produced from the ignition of the nascent oxide of carbon. As fast as this gas is formed, it takes fire and burns away, being converted into carbonic acid gas. Oxide of carbon appears to be formed in those combustions of carbon, where the oxygen is supplied slowly and with difficulty; carbonic acid gas, where it is supplied rapidly and in large quantities. Hence, when we heat the oxides of mercury with charcoal, we obtain carbonic acid; when the oxides of iron, we evolve oxide of carbon.

We have every reason to believe that oxide of carbon is one of the gases produced during animal and vegetable decomposition, and as it is highly noxious, it may contribute to their injurious effects.

It is observed, that as oxygen, by combining with carbon to form carbonic acid, becomes heavier, we might naturally expect that carbonic oxide, containing twice as much carbon, should be heavier still; but this does not follow. Carbonic acid is heavier than oxygen, by precisely the additional weight of the carbon, because this last has assumed the aëriform condition, within the same volume as the oxygen. The sp. gr. of carbonic acid being 1.527, if we deduct that of the oxygen, 1.111, we have .416 for the sp. gr. of aëriform carbon in the gas, and as this is combined with only half a volume of oxygen, which is expressed by .555—this added to the weight of the carbon =.971[†] for the gravity of the carbonic oxide, which is to be regarded, therefore, not as a mere solution of carbon in oxygen, but as a combination of aëriform carbon with oxygen gas.

CARBURETTED HYDROGEN GASES.

1. History.—*Some of these gases must have been for a long time, more or less known to mankind;* as their occurrence is frequent in the mud of marshes, in coal mines, in the matter emitted from burning combustibles, and from the ultimate results of animal digestion, &c.

But we owe the accurate knowledge of them to a few modern philosophers, among whom Mr. Dalton, Dr. Henry, and Dr. Thomson, are conspicuous.[*]

2. General view.—*It seems, at first, as if there must an immense number of carburetted hydrogen gases;* since we can scarcely operate by destructive processes, upon any animal or vegetable matter

---

[*] The following statements of facts are drawn principally from the writings of Dr. Henry and Dr. Thomson.

[†] .972 is the number we have before stated.

without obtaining inflammable gases, that differ in sp. gr.; in combustibility; in the quantity of oxygen required to saturate them; in the intenseness of light emitted while they are burning, and in many other particulars. The ablest analysts, however, among whom none stand higher than the gentlemen already named, are of the opinion that only a few species have been distinctly established, and that the apparent diversity arises from innumerable mixtures of these with each other, with other gases, and with various vapors derived from the substances employed. According to this opinion, which is probably correct, *the compounds of carbon and hydrogen exist in definite proportions only*, "with this peculiarity, that they differ from each other, not so much in the relative proportions of their elements, as in the number of volumes or atoms, condensed into a given volume."*

3. CONSTITUTION OF THE THREE VARIETIES THAT ARE BEST KNOWN.—*Dr. Henry.*

	Sp. gr.	Prop. by weight, carb. hyd.	Prop. in vol. carb. hydro.	
1. Carburetted hydrogen,	0.555,	6 : 2	1 : 2	condensed
2. Olefiant,	0.972,	12 : 2	2 : 2	into one
3. Super-olefiant,	1.458?	18 : 3	3 : 3	volume.

In the olefiant and the super-olefiant—the carbon and hydrogen of each gas bear the same relation to each other, and the gases differ only in the condensation of their elements.—In the olefiant gas, one volume contains two of each of the elements; in the super-olefiant three.

The gases that are best known, are divided conveniently into light and heavy carburetted hydrogen gases; of the former, there is one variety; of the latter, there are two or more.

LIGHT CARBURETTED HYDROGEN.†

1. PREPARATION.

(*a.*) *By stirring* with a stick, *the mud at the bottom of any stagnant water;* bubbles of gas will rise, which may be inflamed by a lighted taper at the surface, or they may be collected by an inverted pitcher, filled with water, or by a bottle filled in the same manner, and having a funnel in its mouth.

This gas contains in mixture, about $\frac{1}{20}$ of carbonic acid, which may be removed, by washing with lime water, or with solution of caustic potash; there is also present from $\frac{1}{15}$ to $\frac{1}{20}$ of nitrogen gas.

---

* Dr. Henry.

† Formerly called hydro-carburet and carbonated hydrogen. It is also called proto-carburet of hydrogen, heavy inflammable air of marshes, &c. but the name in the text is generally used.

b. The gas distilled from mineral coal—after purification with liquid potash to remove the carbonic acid, and with chlorine* to remove the olefiant gas, is also sufficiently pure, and probably the same would hold nearly true of the gases obtained by heating the following substances.

(*c.*) Anthracite of Pennsylvania and of Rhode Island, the latter moist;† kernels of the hickory nut, and of other oleaginous nuts and seeds; common woods, as oak, and maple, pine and pine knots; tartar; recent bone; moist charcoal; acetate of lead, and acetate of copper; spermaceti; tallow, wax, &c.

(*d.*) *In these mixed gases, there are variable proportions of carbonic acid*—of olefiant, and perhaps sometimes of super-olefiant gas, and various vapors.

2. Properties of light carburetted hydrogen gas.‡

(*a.*) *Colorless and tasteless, not absorbable by water*, which, however, after having been previously boiled, takes up about $\frac{1}{64}$ of it volume.

(*b.*) *Odor slight*—when it is otherwise, it is derived from mixture with other gases and vapors, especially when the gas is distilled from bituminous coal.

(*c.*) *Sp. gr.* .555, *air being* 1; consequently, 100 cubic inches weigh, at mean temperature and pressure, 16.944 grains, just half as much as oxygen gas. Its sp. gr. is thus obtained by calculation; it consists of 1 vol. vapor of carbon, which weighs .4166§+2 vol. of hydrogen, $.0694 \times 2 = .1388 = .555$, which is exactly the weight of carburetted hydrogen obtained by experiment.

(*d.*) *Extinguishes burning bodies, but is itself inflammable; burns from a jet, with a flame, which is yellow or variously tinged*; its power of illuminating is much greater than that of hydrogen gas.

(*e.*) *Mixed with from* 6 *to* 12 *volumes of atmospherical air, it explodes with violence by contact of a lighted taper.*

(*f.*) *More violently with oxygen gas*—the latter must exceed the inflammable gas in volume, but must not be over two and one fourth times its bulk.

(*g.*) *Loses its combustibility, if rarefied, so that the pressure is less than one fourth part that of the atmosphere.*

---

* Chlorine has the property of removing the heavy species of carburetted hydrogen, to form with it a peculiar compound, the *chloric ether*, which has been regarded, but erroneously, as an oil. This property of chlorine must be repeatedly mentioned in giving the account of the carburetted hydrogen gases, and will be again illustrated in its proper place.

† See Am. Jour. Vol. X, p. 331.

‡ That obtained from the marshes is the purest variety.

§ For carbonic acid has the sp. gr. 1.527, from which deduct that of the 1 vol. of oxygen which it contains, 1.111, which leaves .416 for the weight of the carbon in vapor.

(*h.*) Carbonic acid and other gases, also diminish its inflammability.

(*i.*) *Its complete combustion requires more than two volumes of oxygen*—two are consumed, and carbonic acid, equal in volume, to the inflammable gas, is produced and water is formed.

(*j.*) There being in carbonic acid exactly its volume of oxygen, it follows that half the gas used went to form water along with the hydrogen, of which there were therefore 2 volumes, and this, along with 1 of gaseous carbon, existed in the compass of 1 volume.

(*k.*) It hence[*] results that the light carburetted hydrogen gas is composed for 100 cub. inches, at med. temp. and pressure, of

charcoal,	12.69 grains,	74.87 grains.
hydrogen,	4.26 "	25.13 "
	16.95[†]	100.00

(*l.*) On respiration and animal life, its effects are eminently noxious, and speedily fatal.

(*m.*) Not decomposed by electricity, nor by heat in ignited tubes, unless very intense, as stated above.

4. Constitution.—Two volumes of hydrogen and one volume of gaseous carbon, condensed into one volume; 1 equivalent of charcoal, =6+2 of hydrogen, =8 for the equivalent of the compound.

OLEFIANT GAS.[‡]

1. History.—*Discovered at Haarlem, in Holland*, in 1796, by the associated Dutch chemists; but Mr. Dalton, of Manchester, gave the first accurate account of its composition.

2. Name.—*With chlorine, in equal volumes, it is condensed into a substance resembling an oil; hence the name, from oleum fio;* the compound substance produced, being however, not an oil, the name was unappropriate, but it is still generally retained.

3. Preparation.[§]

(*a.*) *Alcohol* 1 *measure, sulphuric acid* 2 *or* 3*;* mix them cautiously, in a retort, of which they must not occupy more than ¼ of the body. Gentle heat is gradually applied—the mixture soon becomes black, froths, and emits gas, which, when it burns quietly with a bright flame, may be saved; it is received over water.

---

[*] 16.98.—Dr. Turner. 16.94, on p. 401, (*c.*) of this work.

[†] For carbonic acid, with 1 vol. carbon and 1 of oxygen, weighs 46.597 grains for the 100 cub inches, deduct the weight of the oxygen, 33.888, leaves 12.70 nearly, for the weight of the carbon in vapor, and the weight of hydrogen being, for 100 cubic inches, 2.118; twice that sum is 4.236, and this +12.70 =16.986. These numbers are taken from Brande's Tables, and vary slightly from those quoted elsewhere in the pages of this work.

[‡] Or heavy carburetted hydrogen gas, bi-carburetted, and per-carburetted hydrogen, and hydroguret of carbon. The first name, that of olefiant gas, is generally employed.

[§] By passing the vapor of alcohol over ignited siliceous, or argillaceous earth, nearly pure olefiant gas is obtained.

(*b.*) As the mixture puffs up very much, especially towards the end of the process, *the heat must be very carefully managed*, and should never exceed that of a chafing dish.

(*c.*) Sulphurous acid comes over, which the water will absorb, and carbonic acid is formed, but this, as well as the other gas, is removed by solution of caustic alkali.

(*d.*) The olefiant gas is derived from the alcohol, whose constitution is altered by the sulphuric acid, principally, as is imagined, by its uniting with the water.*

4. PROPERTIES.

(*a.*) *Invisible—little odor, except from sulphuric ether*, which is formed in the process; I have always observed however, that it retains the ethereal smell for a long time. Water 8 vols. absorbs 1 of this gas.

(*b.*) Sp. gr. 972,† air being 1. It is remarked that nitrogen gas, carbonic oxide, and olefiant gas have the same gravity;‡ and that 100 cubic inches, at the medium temperature and pressure therefore weigh 29.64 grains. As it consists of 2 vols. of vapor of carbon, and 2 vols. of hydrogen, its sp. gr. is easily obtained by calculation, thus. Twice the sp. gr. of hydrogen gas, $0694 \times 2 = 1388 +$ twice the sp. gr. of the vapor of carbon, $4166 \times 2 = 8333$, and this number $+1388 = .972$.

(*c.*) *Extinguishes burning bodies, but issuing from a jet, and kindled by a candle, this gas burns with extreme brilliancy*, the flame resembling that of the brightest lamp; it far surpasses simple carburetted hydrogen.

(*d.*) *Mixed, 1 vol. with 3 vols. of oxygen gas, and inflamed, it detonates with great violence*, and much care is requisite to avoid accidents. If done in glass vessels, they should be small and strong, but it is better to use plate tin, or copper tubes.

(*e.*) *The explosion may be made in a detonating eudiometer tube*, by electricity, but only a cubic inch of the mixed gases should be employed.

(*f.*) *One volume* of this inflammable gas, *requires* 3 *of oxygen* for saturation, and gives two volumes of carbonic acid gas.

(*g.*) Dr. Henry remarks, that in order to insure the perfect combustion of the gas, it should be mixed with 5 volumes of oxygen gas, of at least 90 per cent. purity.

---

* For a more particular view of the theory, see alcohol.

† Thomson's First Principle, Vol. I, p. 149.

‡ The Dutch chemists made that of olefiant gas, .909—Dr. Henry, some years ago, .967—Saussure Jr. .9852.

5. MODE OF ESTIMATING ITS COMPOSITION.

(*a.*) *If too little oxygen be used, charcoal precipitates unburnt*, and the volume of the residue is greater than that of the original gases.

(*b.*) Upon the same principles of calculation as those upon which the composition of the light carburetted hydrogen gas was determined, it follows that in 100 cubic inches there are—

Charcoal,	25.38	85.63 grains,	100.
Hydrogen,	4.26	14.37 "	16.71
	29.64*	100.00	116.71†

(*c.*) Olefiant gas has therefore 100 grains of charcoal united to 16.71 of hydrogen, while the light carburetted hydrogen has the same weight of carbon, with 33.41 of hydrogen, just double; in other words, the carbon being given, it has half the hydrogen, and the hydrogen being given, it has double the carbon.

6. CONSTITUTION.

As, in the combustion of olefiant gas, 3 vols. of oxygen disappear, water is formed, and 2 vols. of carbonic acid are produced, it is evident that as oxygen does not change its volume by combining with carbon, to form carbonic acid, 2 volumes of the oxygen have gone into the carbonic acid with 2 volumes of carbon; the other volume of oxygen has formed water, and as two volumes of hydrogen are demanded for this purpose, it follows that each volume of olefiant gas contains 2 volumes of carbon, +2 volumes of hydrogen, =2 equivalents of each. The compound will therefore weigh 12+2=14, its equivalent.‡

If 2 grains of sulphur be heated over mercury, with 1 cubic inch of olefiant gas, 2 cubic inches of light carburetted hydrogen will be obtained, and charcoal precipitated.—*Ure.*

7. MISCELLANEOUS.§

(*a.*) In olefiant gas there is so large a proportion of carbon, that when a jet of the flame is permitted to play against a white earthen plate, it covers it with charcoal, and the jet burning freely in the air, emits a column of lamp black.

(*b.*) Olefiant gas is decomposed by electricity; and by ignition in porcelain tubes; products, charcoal and hydrogen, the latter in a volume double to that of the gas decomposed.

In the experiment with the tube, by varying the heat, we can cause it to deposit more or less charcoal.

---

* Dr. Turner states this number at 29.65, and that for two volumes of hydrogen at 4.23.

† See p. 403, (4. *b.*)

‡ Henry, Vol. I, p. 425, 10th Ed.

§ The action of chlorine and iodine upon the carburetted hydrogen gases, will be considered under those heads.

SUPER-OLEFIANT GAS.

1. **Remark.**—We mention this gas, (whose distinct existence is highly probable, but not perhaps fully proved,) out of respect to Mr. Dalton, and Dr. Henry, to whom science is so much indebted, especially in relation to the inflammable gases.

2. **History.**—Dr. Henry, in the Phil. Trans. for 1821, has given an account of the discovery of this gas by Mr. Dalton, which has not been obtained in a separate form, but mingled with other varieties, in the gases obtained from oil, coal, &c.

3. **Properties.**

(*a.*) For complete combustion, 1 *volume requires* 4½ *of oxygen*, and produces 3 of carbonic acid.

(*b.*) *Sp. gr.* estimated at 1.4, but Dr. Henry thinks that if constituted as he supposes, of 3 volumes of gaseous carbon, and 3 volumes of hydrogen, condensed into 1 volume, its specific gravity must be 1.458, derived from multiplying the sp. gr. of hydrogen, .0694, and that of gaseous carbon, .4166, each by 3, and adding the products together.

(*c.*) A portion of a gas which contained more than 40 per cent. of the super-olefiant, was cooled by muriate of lime and snow, but no liquid was deposited from it; it was condensible by chlorine, but the product has a peculiar odor, unlike that of chloric ether.

OTHER COMPOUNDS OF CARBON AND HYDROGEN.

It is believed that there are four or five more of these compounds, in which the constituent principles bear the same proportion to each other, but differing in the degree of condensation.

1. It is supposed that a compound may exist of 1 volume of carbon, and of 1 of hydrogen, condensed into 1: the sp. gr. of this would be, for the carbon vapor, .4166, and for the hydrogen, .0694, the sum of which would be, .4860; but this has not yet been discovered, although Dr. Thomson and Dr. Henry, concur in suggesting that it may yet be found.[*]

2. Dr. Thomson inferred that another compound might exist in the vapor of ether, in union with 1 volume of aqueous vapor. He supposed that it might consist of 4 volumes of vapor of carbon, and 4 volumes of hydrogen, condensed into 1 volume; it would of course have twice the sp. gr. of olefiant gas, that of 1.9444: it would require 6 vols. of oxygen, for its entire combustion, and would produce 4 vols. of carbonic acid.[†] Its equivalent would of course be 28, composed of 4 × 6 for the carbon, and 4 × 1 for the hydrogen.

Dr. Thomson gave it the provisional name of quadro-carburet. This compound has since been discovered by Mr. Faraday. In Mr.

---

[*] Perhaps as a constituent of coal gas.

[†] Hence, adding the number representing the sp. gr. of aqueous vapor, Dr. Thomson inferred that the sp. gr. of the vapor of ether must be 1.9444+06250=2.5694.

Gordon's patent oil gas lamp, the gas is compressed by a force of 30 atmospheres, and a limpid fluid* is obtained, which appears to contain several compounds of carbon and hydrogen. If this fluid be heated by the hand, and the vapor condensed into a tube, cooled to 0, it becomes a fluid, which remains such only below 32° Fahr. and even before that temperature is attained, it is reconverted into vapor, which burns with a brilliant flame. Its sp. gr. is 1.9065, very near that calculated for it by Dr. Thomson, before its discovery. It is slightly absorbed by water; more by alcohol, but is evolved from the latter, with effervescence, by water. At 0 it is again condensed, and the fluid having the sp. gr. of 0.627, is the lightest known. Sulphuric acid absorbs 100 times its volume, and its color is darkened, but no sulphuric acid is disengaged.

Its analysis by oxygen is exactly what was predicted by Dr. Thomson; as to the quantity of gas required, the carbonic acid produced, the proportions of its constituents, and the equivalent number, as already stated.

3. Dr. Thomson supposes that the vapor of the fluid distilled from coal tar, and which is, from its similarity to mineral naptha, called by the same names, consists of 6 equivalents of vapor of carbon +6 of hydrogen, condensed into 1. Its equivalent number is of course 42; it requires 6 vols. of oxygen for its complete combustion, and there are produced 6 of carbonic acid. This compound is supposed to exist in the coal gases, and as their light is in direct proportion to the quantity of carbon which they contain, it is obvious that upon this view, the vapor of naptha will give three times as much light as olefiant gas. Its sp. gr. must, of course be 2.9166. In pure naptha, potassium remains unoxidized, which proves the absence of oxygen.

4. In the liquid obtained by the condensation of coal gas, Mr. Faraday discovered another compound of carbon and hydrogen. This fluid, when recent, boils at 60° Fahr.; one tenth being exhaled, the boiling point rises to 100°, and the whole is not evaporated till it rises to 250°. It thus appeared probable that there were different compounds, differing in volatility, and by condensing the vapor at different temperatures, he attempted to obtain them separate. The boiling point appearing more constant between 176°, and 195°, than any where else, he carried on the distillation within those limits, and by repeating it, and condensing the vapor at 0, he obtained a fluid which he called *bi-carburet of hydrogen.*

Its properties are as follows; it is a transparent colorless fluid, smells like oil gas, or almonds; at 60°, sp. gr. .850, and that of its vapor 2.776. At 32°, it becomes solid and crystalline; at 0 transparent and crumbles into grains, having nearly the hardness of loaf sugar. Boiling point, 186°, evaporates spontaneously; soluble, in fixed and volatile oils, and in ether and alcohol, from which it is thrown down by water.

---

* About 1 gallon for 1000 cubic feet of good gas.—Phil. Trans. 1825, p. 441.

It burns readily and brilliantly, and with much smoke; in oxygen gas its vapor rises and forms a detonating mixture. Potassium retains its lustre in it, even when heated. By passing it in vapor through an ignited tube, charcoal is deposited, and carburetted hydrogen obtained. Its analysis was performed by detonation with oxygen; and by passing it over ignited oxide of copper; carbonic acid and water were the only products, and as there is no oxygen in it, it follows that it is composed of carbon and hydrogen only. It requires 750 measures of oxygen to burn 100 of its vapor; 600 unite with 600 of carbon vapor, and 150 with 300 of hydrogen, and therefore its constitution is 6 equivalents of carbon, and 3 of hydrogen, and of course the equivalent of the compound is $6 \times 6 = 36 + 1 \times 3 = 39$. The sp. gr. of its vapor is easily inferred; for the weight of the vapor of carbon $.4166 \times 6 = 2.4996$, and that of hydrogen $.0694 \times 3 = 0.2082 = 2.7078$, and this is very near to the number obtained by Mr. Faraday.

NAPHTHALINE.

A substance to which this name has been applied, was first observed by Mr. Garden and afterwards examined by Dr. Kidd of Oxford Univ.

It is obtained from coal tar; the naptha passes first by a very gentle distillation, and afterwards the naphthaline in vapor, which condenses in the neck of the retort, in the form of a white crystalline solid.

Properties.—Sp. gr. 1.048; taste pungent and aromatic; odor peculiar, and said to resemble that of narcissus; to the touch smooth and unctuous; color white; lustre silvery; soluble in alcohol and ether, in olive oil, in oil of turpentine, and in naptha; not very inflammable, but, when kindled, burns rapidly, with much smoke; fusible at 180°; evaporates at the common temperature and boils at 410°; its condensed vapor readily crystallizes in thin transparent laminæ. By Dr. Thomson's analysis, naphthaline consists of one equivalent and a half of carbon 9, and of 1 of hydrogen, and its own equivalent is therefore 10. According to Dr. Thomson's views it is, therefore, a *sesqui-carburet*. It appears to form, with sulphuric acid, another peculiar acid, to which the name of sulpho-naphthalic has been given, and its compounds have been called sulpho-naphthalates. There is also an acid, apparently formed by the action of nitric acid. It is scarcely necessary to detail the particulars of these unimportant compounds.*

---

* Phil. Trans. 1825, Part II, and Ann. of Philos. XXVII, 44, and New Series, VI, 136. Eng. Quar. Jour. VIII, 289. Murray. Turner.

Mixed gases; obtained by heating various combustible bodies, as tallow, alcohol, ether, bituminous coal, &c.

Remark.—Although, as has been already observed, these gases are, in all probability, mixtures of *the varieties* that have been described, they do, in practice, *present some peculiarities worthy of being noted.*

I. Coal gas.

(*a.*) There is so much variety in the properties of the gases obtained by heating mineral coal, that they are hardly worthy of being grouped together, except on the ground that they are obtained from a common material.

(*b.*) Bituminous coal, distilled in an iron retort, affords, besides the permanent gases, tar and solution of carbonate of ammonia.

(*c.*) *The gas varies in quality*, even from the same coal, *at different stages of the process*, according to the degree of heat and the manner of applying it; of course, it varies with different specimens of coal.

(*d.*) Dr. Henry remarks, "within certain limits, the more quickly the heat is applied, the greater is the quantity and the better the quality, of the gas obtained from coal; for, too slow a heat expels the inflammable matter in the form of tar."*

(*e.*) *The gas declines much in quality towards the end of the operation*, although we still continue to obtain large quantities.

(*f.*) The useful part of the gas is composed of mixtures of light and heavy carburetted hydrogen, in endlessly varied proportions.

(*g.*) The useless gases are carbonic acid, oxide of carbon, nitrogen and sulphuretted hydrogen,† and sometimes ammonia, (and sulphurous acid gas?)

(*h.*) *The disagreeable smell* arising from sulphuretted hydrogen, and probably a little sulphuret of carbon, *may be washed out by cream of lime*, without injuring the combustibility of the gas.

(*i.*) *The best gas has the sp. gr. of* at least 650, air being 1, "and each volume consumes about 2¼ volumes of oxygen and gives 1¼ volume of carbonic acid."

(*j.*) "*The last portions have a sp. gr. as low as* .340, and each volume consumes about .8 of a volume of oxygen gas and gives about .3 of a volume of carbonic acid."

(*k.*) *Chlorine*, applied in a manner hereafter to be pointed out, *detects from* 13 *to* 20 *per cent of olefiant gas;* the rest is chiefly light carburetted hydrogen.

---

* Phil. Trans. 1808, 1820, 1824.

† Dr. Henry refers us, for the method of separating them, to his memoirs above quoted, to Manchester Memoirs, and Annals of Philosophy, XV.

(*l.*) *The last portions contain hardly any olefiant gas;* they consist of light carburetted hydrogen, and much hydrogen and carbonic oxide, which is the reason that they afford so little light during their combustion.

(*m.*) *There is great uncertainty and variety in the quantity and quality of gas obtained from coal.*—Dr. Henry considers it as an approximation to truth, to suppose, that 112 lbs. of good coal may afford from 450 to 500 cubic feet of gas, "of such quality, that half a cubic foot per hour is equivalent to a mould candle of six to the pound, burning during the same space of time."

(*n.*) I have often obtained a very bright burning gas from Richmond (Va.) coal; at other times a gas producing a very pale flame.

(*o.*) *Anthracite of Pennsylvania and of Rhode Island,** *afford* much gas,† chiefly *light carburetted hydrogen,* but it is unfit for illumination; most authors state that the anthracties afford little or no gas. That of Wilkesbarre gave, in my trials, 40 wine pints from 886 grains of the coal, while the specific gravity of the coal was increased from 1.65 to 1.77,‡ and several other varieties of American anthracite yielded large quantities of inflammable gas.

II. OIL GAS.

1. HISTORY.

(*a.*) The familiar use made of animal oils, to afford by their combustion, artificial light, naturally suggested the project of decomposing them to obtain gas.

(*b.*) Dr. Henry, in a memoir in Nicholson's Journal for 1805, appears to have first brought this subject into notice, and to have proved that next to the pure olefiant, the gas from oil is the best adapted for artificial illumination.

2. PREPARATION AND PROPERTIES.

(*a.*) *By allowing spermaceti oil, or even refuse whale oil,* (as the purity of the oil is not material,) *to fall drop by drop,* from a reservoir furnished with a stop cock, and connected by a tube with an iron bottle or cylinder, upon fragments of bricks, or, as practised in New York, fragments of anthracite, heated to a cherry red.

(*b.*) A condensing vessel should be interposed between the furnace and the gazometer, to receive the undecomposed oil.

(*c.*) *A wine gallon of oil affords* 100 *cubic feet of gas,* whose specific gravity exceeds .900; more than .40 of this gas is condensible by chlorine; 100 volumes require 200 of oxygen to saturate them and produce 158 of carbonic acid.

---

* The latter must be moist.

† It is not easy to say how much of this gas arises from water; the increase of sp. gr. in consequence of ignition, seems however to imply that a lighter constituent of the mineral has been expelled.

‡ Am. Jour. Vol. X, p. 355, and Vol. XI, p. 78.

(*d.*) Wigan coal has been esteemed the best in England; the gas from this coal, required, on an average, only 155 volumes of oxygen to 100 of the coal gas, and gave 88 measures of carbonic acid.

(*e.*) As the inflammable gases produce light just in proportion to the quantity of carbon they contain, it follows, that oil gas is nearly or quite as powerful as gas from Wigan coal.

3. MISCELLANEOUS.

(*a.*) Mr. Brande estimates, that to produce a quantity of light equal to that of ten wax candles, burning for one hour, there are required 2600 cubical inches of olefiant gas, 4875 of oil gas and 13120 of coal gas.

(*b.*) Dr. Henry suggests that this estimate is, as regards coal gas, rather low, and is disposed to consider 1 volume of oil gas as equivalent to 2 or 2½ of coal gas.

(*c.*) The late Mr. Creighton, of Glasgow, considered 2 volumes good coal gas as equal, in affording light, to only one of oil gas, and valuing the quantity of light given by one pound of spermaceti candles at 1 shilling, he estimated the cost of an equal effect from sperm oil, burning in an Argand's lamp, at 6¼*d.* that from whale oil at 4½*d.* and that from coal gas at 2¾*d.* "Twenty cubic feet of coal gas, or ten of oil gas, he considers as equivalent to a pound of tallow, and 5000 grains of spermaceti oil to 7000 of tallow or 1 lb. avoirdupois."

(*d.*) Dr. Henry sums up the comparative claims of oil and coal gas, by saying, that for oil gas, vessels and tubes of half the size are sufficient;* no washing is needed; there is no residuum; the light is brighter and the heat less; but that still, in large establishments and in countries where coal is cheap, the latter will be preferred on the score of economy.

(*e.*) The best criterion of the illuminating power of a gas is the quantity of oxygen required for its perfect combustion,† and the amount of carbonic acid produced; specific gravity is deceptive, for it may be affected by foreign gases, for instance, by carbonic oxide or by carbonic acid.‡

(*f.*) It appears that a very valuable illuminating gas is obtained by decomposing cotton seed by a well managed heat. Prof. Olmsted has shewn that it is both economical and effectual.§

(*g.*) Coal gas is obtained by decomposing coal in an iron retort; the tar is received in a condensing vessel, and more continues to be deposited by the passage of the gas through vertical tubes kept cold. The gas, under strong pressure, is passed through lime diffused in water, or through successive layers of hydrate of lime, to remove carbonic acid, sulphuretted hydrogen, &c.; it is finally received in a gazometer, (see p. 214,) thence distributed by tubes, and burned at proper orifices furnished with stop cocks.

---

* Oil gas, being free from sulphuretted hydrogen, needs no purification, and is therefore peculiarly fitted for domestic use.

† It is suggested that condensation by chlorine may be a test equally decisive.—*Comm.*

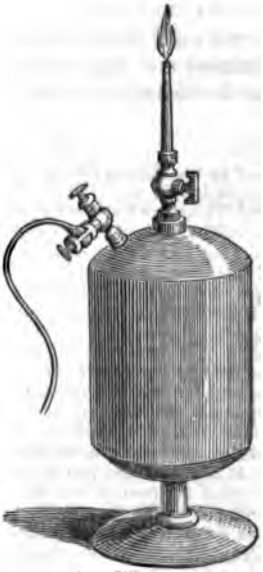
‡ Henry's Chem. Vol. I, p. 482, 10th ed.

§ Am. Jour. Vol. XIII, p. 194, and Vol. X.

(*h.*) It is now evident, that the illuminating power of gases is dependent not only upon the quantity of olefiant gas in them but upon the other compounds containing still more carbon, as the quadro-carburet, the vapor of naphtha, &c.

(*i.*) Mr. Daniel employs resin,* dissolved in oil of turpentine; it falls, drop by drop, into the retort, and the volatile oil, by passing over in vapor, is recovered. This gas is employed by Mr. Gordon in his portable lamps, and is said to be equal to oil gas.

PORTABLE GAS LIGHT.



"One of the greatest obstacles to the general employment of gas lights, as a substitute for candles and lamps, is the necessity of pipes leading from gazometers, to all situations where the light is wanted. The condensation of the gas in strong metallic receivers, has been resorted to in order to obviate this difficulty. This process may be illustrated by means of the apparatus described for the impregnation of water with carbonic acid.

"It is only necessary to exchange the communication with the reservoir of carbonic acid gas, for a similar communication with a reservoir of olefiant gas, and the copper vessel being first exhausted of air, to condense the gas into it. The syphon used to draw off the carbonated water, is replaced by a tube and cock, terminating in a capillary perforation. Through this, the gas may be allowed to escape in a proper quantity to produce a gas light when inflamed."—*Dr. Hare.*

SAFETY LAMP OF SIR H. DAVY.

1. Remarks.

(*a.*) It has long been notorious that a deadly gas infests the mines of bituminous coal, called by the miners, the fire damp or wild fire, and that the most deplorable accidents have frequently resulted from its explosion.[*]

---

* Dr. Hare, several years ago, employed common rosin, in New York, and it is now used there to afford gas light; he obtained also a substance, rising in distillation, which not a little resembled naphthaline.

(*b.*) It probably arises from the decomposition of water by the coal, and issues from the crevices of the rocks and of the coal strata, particularly from places called blowers;[†] it is but little more than half as heavy as common air, and therefore it occupies first the roof of the mine.[‡]

2. History.

(*c.*) *The first scientific account of the gas* of coal mines, *was published in* 1806, *by Dr. Henry,*[§] who proved that it is the same as the light carburetted hydrogen.

(*d.*) *Sir Humphrey Davy, some years later, visited the coal mines in person,* descended with the miners into the regions of the fire damp, obtained specimens of the gas and subjected them to a chemical examination.[‖]

(*e.*) *He discovered several important facts,* and by a train of ingenious and philosophical reasoning, was led to a happy conclusion in the discovery of the safety lamp.

---

[*] In the Felling Colliery, 92 miners perished at one time, and 23 at another, and in another 57 were killed in the same way.—*Murray.*

[†] These are fissures laid open in working the mines.

[‡] When mixed with the air of the mine, it is said to produce a misty appearance, as I had opportunity of observing at the mines of Newcastle, in England, in Nov. 1805. If the quantity of gas in the mines is small, it is harmless; but if great the consequences are sometimes extensively fatal. The catastrophe proceeds from the extreme inflammability of this gas, and its disposition to explode when mixed with the atmosphere. Unhappily, in these dark regions, no work can be done without artificial light. In some places, they work by the feeble sparks produced by rubbing flint against a jagged steel wheel. In other places, they carry a candle or a torch, and whenever the fire is communicated to a large quantity of this gas mixed with common air, the explosion is as sudden and violent as that of gun powder. Sometimes, the mine, machinery, and miners are blown up, with the loss of all their works, and of course of the lives of a large proportion of the people.

If the walls and roof of the mine are so strong as not to give way, the expansive force of the steam and of the elastic vapors rarefied by the sudden heat, forces every thing along the narrow chamber of the mine, as a bullet is driven from a gun. In the mines where the production of this gas is not very rapid, the miners set fire to it frequently, and thus explode it in small quantities without danger. This they do by means of a candle tied to the end of a long pole, which they elevate into those parts of the roof where the gas commonly collects. Sometimes they tie a candle in the middle of a rope, and two men, by pulling the rope at the two ends, bring the candle into contact with the gas. But where it is produced too copiously to be managed in this way, the miners fix wooden pipes all along the roof of the mine, with branches carefully communicating with those places from which the gas issues, and all these pipes are connected with one main shaft which terminates in a chamber where is a fire place with a very tall chimney. Here a fire is constantly maintained, and the rarefaction of the air produces a constant stream from all parts of the mine to this spot, where the gas burns quietly away without injury.

When the inflammable air is very copious, it is said to burn at the top of the chimney, and to produce heat enough to maintain the combustion without any additional fuel.

[§] Nicholson's Jour. XIX, 149.

[‖] Phil. Trans. 1816; History of the Safety Lamp, 1818; Phil. Mag. I, 50. 887.

3. SOME PECULIAR PROPERTIES OF THE FIRE DAMP.

(*a.*) *The most explosive mixture of this gas with common air, was found to be* 1 *measure of the inflammable gas to* 7 *or* 8 *of air; it explodes feebly with* 5 *or* 6 *volumes of air, and with only* 3 *or* 4, *it does not explode at all;* it is still explosive with 14 volumes of air, but with more, a taper burns in it only with an enlarged flame.

(*b.*) Charcoal in active combustion, and iron heated to redness or even to whiteness, did not kindle this mixture; *it was*, however, *exploded by iron in a state of brilliant combustion*, and the smallest point of flame, owing to its high temperature, produced instant explosion.

(*c.*) The fact which led immediately to the discovery of the safety lamp, had been observed before by Dr. Wollaston, and was this, "that *an explosive mixture cannot be kindled in a glass tube so narrow as one seventh of an inch in diameter.*"

(*d.*) Two separate reservoirs filled with an explosive mixture, being connected by a metallic tube one sixth of an inch in diameter, and one and a half inch in length—the explosion could not be made to pass into the one, when the other was set on fire.

(*e.*) It was also discovered that fine *wire sieves, or wire gauze being in fact only short tubes, form, upon the same principle, an effectual barrier between two portions of explosive gas*, which will not communicate through such a partition.

(*f.*) It was found also that "a mixture of fire damp and air, in explosive proportions, was deprived of its power of exploding by the addition of about one seventh of its bulk of carbonic acid or nitrogen gas."*

(*g.*) Sir Humphry Davy was thus led to an attempt to combine both these principles by the construction of a lamp, which being fed with only a limited supply of air, might be occupied more or less by carbonic acid and nitrogen, and which, by having small metallic apertures, might prevent the spreading of combustion into the surrounding atmosphere, should that be in an inflammable or explosive state.

(*h.*) After various modifications and improvements, the safety lamp is now constructed of wire gauze, that is, the flame is surrounded by a wire sieve, so fine as to have at least 625 apertures in a square inch.

(*i.*) It is a cylinder 2 inches in diameter; it rises 10 or 12 inches above the flame; the wire gauze is double at the top, where the greatest heat exists, and no part of it is impervious to air, except that which contains the oil, and which is furnished with means of raising and trimming the wick, and recruiting the oil, without opening the lamp in the explosive atmosphere.

---

* Many miners perish from the prevalence of these gases after the explosion; carbonic acid being formed and mixed with the nitrogen which is left.

(*j.*) When the proportion of the fire damp in the air is $\frac{1}{12}$ the wick of the lamp is seen surrounded by a faint blue flame.

(*k.*) When the proportion is increased to $\frac{1}{7}$, $\frac{1}{6}$, or $\frac{1}{5}$, the lantern is filled with the flame, burning green, as I have observed it in labotory experiments; still, the flame, even when the wire is red hot, does not communicate to the exterior air, although it should be in an explosive state.*

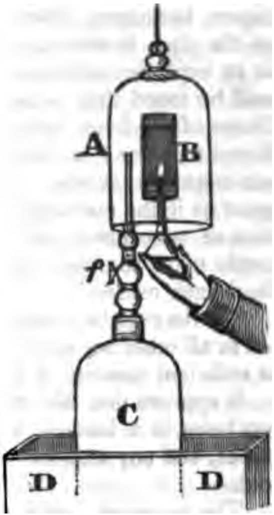
(*l.*) Should danger arise from a current of explosive gas passing through so rapidly as to heat the wire to such a degree that it might inflame the air; still the increase of the cooling surface, either by diminishing the size or increasing the number of the apertures, would obviate the danger, for the safety of the instrument is supposed to consist in the cooling powers of the wire, reducing the explosive gas below that temperature at which it is inflammable, which temperature is stated to be far above a white heat.†

(*m.*) Even when the noxious gases prevail, so as to extinguish the lamp, and thus threaten life by suffocation, a small coil of platinum wire, hung above the lamp, within the wire gauze cylinder, will continue to glow, and will enable the miner to grope his way through regions otherwise perfectly dark. This combustion is owing to the fire damp, but it does not communicate to the external air; and on coming into better air, the lamp will frequently be rekindled spontaneously.

---

* The miner should, however, then withdraw, because the wire may be so rapidly oxidized as to fall to pieces, and he may be in danger also of suffocation, from the prevalence of irrespirable gases.

† Sir H. Davy's theory of the safety lamp is called in question by M. G. Sibri, (Bib. Univ. Mars, 1827, and Am. Jour. Vol. XIII, p. 179.) who contends that it is not owing to the cooling power of the metal, but to a repulsion existing between flame, and any substance that may be brought near it. It is repelled equally by a rod of glass or porcelain, as by one of metal, and the effect depends not on the nature of the body, but is proportioned directly to its bulk, and inversely to its distance; even two flames will repel each other, and so gross a flame as that of a candle, will refuse to pass between two rods of any kind, (even wood,) brought near to each other on opposite sides of the flame, and near the summit. The repulsion is not all affected by the temperature of the substance. I have repeated these experiments, and find them exact, and the cause is obvious; the repulsion appears to be occasioned by the gas, which is incessantly blowing out from flame, and which striking against any obstacle, reacts, to inflect the flame; just as a current of lava will sometimes stop short, at a wall, rise parallel to, and finally cascade over it, without touching it; this well ascertained fact is owing to the great quantity of aërial matter blown out by lava, and which, meeting with an obstacle, reacts upon it as above described, with respect to flame. Mr. Sibri conceives that the number of wires in the metallic gauze of the safety lamp, is by far too great, and that the same security would be afforded by such a number as would merely give strength to the instrument, without so much impeding the light. I have never felt satisfied with this part of the theory of the safety lamp, given by its illustrious inventor, and am disposed to think that the one suggested above is the principal source of protection; in this opinion I am supported by Prof. J. Griscom, to whom I am indebted for the notice of Mr. Sibris' views.

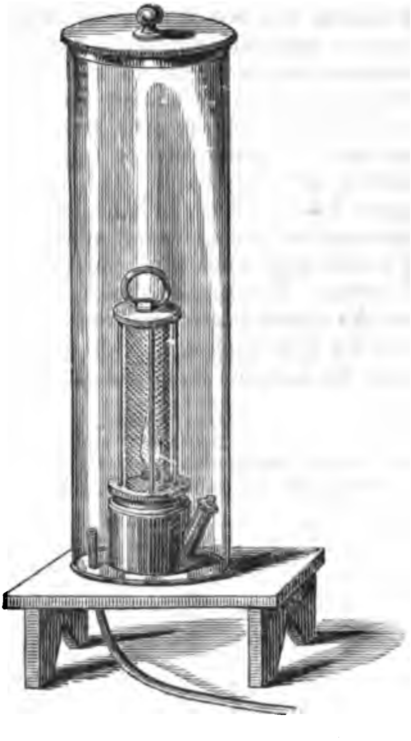


A, is a large bell of common air, held by the hand, or suspended by a string.

B, is a lighted safety lamp, held by an assistant within the jar.

C, An air jar, with cap, stop cock, and tube, filled with carburetted hydrogen, and depressed into the water of the pneumatic cistern, D D, so that by gently turning the key *f*, the inflammable gas flows through the tube, mixes with atmospheric air, penetrates the lamp, and enlarges the flame ; it even fills the whole lamp with a delicate blue or green flame, which ultimately extinguishes the light of the lamp ; but if, when the lamp is nearly extinguished, it be lowered a little, so as to better the condition of the air, it will be rekindled, and then may again be raised into the jar, and so on.—*Comm.*

Figure and Description from Dr. Hare.



"The lamp is seen within a large glass cylinder upon a stool. The cylinder is closely covered by a lid, which will not permit the passage of air between it and the cylinder, and which is so light as to be easily blown off. Excepting the cage alluded to above, the safety lamp differs not materially from those which are ordinarily used. The upper surface of the receptacle for the oil, forms the bottom of the cage, which is so closely fitted to it, and so well closed every where, as to allow air to have access to the flame only through the meshes of the wire gauze. The cage is enclosed within three iron rods, surmounted by a cap, to which a ring for holding the lamp is attached, as seen in the drawing."

"If while the lamp is burning, as represented in the figure, hydrogen, either pure or carburetted, be allowed, by means of the pipe, to enter the glass cylinder, so as to form with the air in it an explosive mixture, there will, nevertheless, be no explosion. It will be found that as the quantity of inflammable gas increases, the flame of the lamp enlarges, until it reaches the wire gauze, where it burns more or less actively, according as the supply of atmospheric air is greater or less. It will, under these circumstances, often appear as if the combustion had ceased, but on increasing the proportion of atmospheric air, the flame will gradually contract, and finally settle upon the wick, which will burn as at first, when the supply of hydrogen ceases."

"If the cage be removed from the lamp, and the experiment repeated in all other respects as at first, an explosion will ensue, as soon as a sufficient quantity of hydrogen is allowed to enter the cylinder."

It appears that Mr. Stevenson invented a lamp, whose light was enclosed in a lantern, to which air was admitted by a number of tubes, and any explosion within did not communicate to the air without.

The principal inconveniences of Sir H. Davy's lamp are, its liability to injury, on account of its delicate texture, and if there is a hole made in it, the explosive atmosphere without may be readily fired; it is evident also that it does not afford a strong light, and the workmen are sometimes tempted if possible, to open it, even in dangerous situations, and accidents are said to have occurred from that cause. Dr. Murray invented a safety lamp, of which an account is given by his son,* founded upon the well known fact, that the inflammable gas occupies principally the upper cavities, and that the air on the floor is ordinarily good. The air for the support of the flame is drawn from the floor, by a flexible tube, passing from the bottom of the lamp, while the chimney at the top, by the strong current which it is constantly discharging, prevents the entrance of gas from that direction. The lamp is also of sufficient strength, and being furnished with a good mirror and lens, it throws a strong light, and it is said that if an explosion should happen in it, it would merely extinguish the light, but would not extend to the atmosphere without.†

---

* Elements, 6th Ed. Vol. 1, p. 609.

† Trans. Roy. Soc. Edin. Vol. VI, p, 31.

COMPOUND OF NITROGEN AND CARBON.

This compound is named here, because, in the strictness of logical arrangement, this is the place for its introduction; but its fuller developement, and that of the connected topics, will be reserved to a more advanced stage of this work, because the subject is complicated and difficult, and requires the previous knowledge of the most important facts of elementary chemistry. These topics will be touched upon again under iron, and the other metals, and finished under the chemistry of animal bodies, from which the principal agents of this family are derived.

CYANOGEN.

1. **Name.**—κυανος, blue.*

2. **Process.**—If prussian blue, 8 parts, be boiled with red oxide of mercury, 11 parts, a crystallizable salt will be obtained, the prussiate or cyanuret of mercury, by heating which, in a dry state, in a retort, we obtain over mercury a gas called cyanogen, which burns with a superb purple and violet flame. It is composed of 2 equivalents of carbon, and 1 of nitrogen.

PRUSSIC ACID, OR HYDRO-CYANIC ACID.

1. **Name.**—Called prussic acid, from prussian blue, the parent substance, from which, as above, the cyanuret or prussiate of mercury is obtained, which affords this agent. The term, *hydro-cyanic*, refers to the union of hydrogen with cyanogen, to form this acid.

2. **Process.**—Decompose the prussiate, or cyanuret of mercury, in a retort by muriatic acid, and condense the volatile product in an ice cold receiver.

3. **Properties.**—It is the most diffusive and virulent poison known; it kills small animals when a drop is applied to the tongue, and a few drops are more than sufficient to extinguish life in a vigorous man. It exists ready formed in the vegetable kingdom, in peach blossoms, and peach kernels, in the bitter almond, in the lauro cerasus, &c. It, or its radical, combines with alkaline and earthy bases, and the prussiates or cyanurets of these bodies furnish us with tests that are highly useful in detecting the metals. The prussic principle is transferred to them, from prussian blue, and these applications may be occasionally mentioned before the subject is fully exhibited.

There are two acids composed of cyanogen and oxygen, called, the one *cyanic*, and the other *fulminic acid;* and one of them is supposed to exist inthe fulminating silver, and in fulminating mercury.

---

* In allusion to Prussian blue.

Sec. IV.—Phosphorus.

1. History and Name.

(a.) *Brandt, an alchemist of Hamburgh, has the credit of discovering Phosphorus,* A. D. 1669, while endeavoring to transmute metals;* Brandt sold the secret to his friend, Kunckel, but deceived him with a false process. Kunckel, having however learned that it was obtained from urine, avenged himself by making the discovery anew.

Mr. Boyle also discovered it in England, and Godfrey Hankwitz, a man instructed by him, vended it at a high price, in a shop still shown in London, near Covent Garden Theatre.

(b.) *In 1737, a committee of the French Academy of Sciences was instructed in the process by a stranger;* it was then, as at first, obtained by evaporating hogheads of putrid urine to dryness, and afterwards distilling the residuum with a strong heat, in a stone ware retort.

(c.) *Margraff,* of Berlin, *by adding muriate of lead to the urine, precipitated phosphoric acid,* in union with oxide of lead, and this was decomposed by distillation with charcoal.

(d.) *In 1769, Ghan, of Sweden, a pupil of Scheele, having discovered that phosphate of lime is the basis of bones,* invented the process now generally followed.

The name signifies light bearer, Φῶς Φέρω.

2. Preparation.

(a.) *Obtained from bones,* by a process to be described under phosphate of lime.—At the same time may be mentioned, the processes by which it is extracted from urine, and from the phosphates of soda and ammonia, and the method of purification; but, for the present, we will consider it as obtained and pure.

3. Properties.

(a.) *Color, after distillation in hydrogen, nearly white, and semi-transparent,* usually however, brownish or flesh red; looks like wax—is insipid—becomes black when suddenly cooled, after being heated to 140° or 160°; but cooled slowly, remains transparent and colorless, or with the translucence of horn. Thénard says that it must have undergone repeated distillations, in order to exhibit these appearances.

(b.) *Solid, brittle in cold weather;* fracture sometimes radiated; sp. gr. 1.714, or 1.77; in mild weather easily cut; in cold weather brittle.†

---

* He imagined that the extract of urine, would enable him to transmute the baser metals into gold and silver, and while heating this substance, the phosphorus was evolved.

† If pure, it is very flexible; 1-600th of sulphur renders it brittle.

(*c.*) *Crystallizes by melting it under water, and when the crust has congealed, it must be pierced, and the liquid interior poured out,* by inclining the vessel; the crystals are needles, or, if the cooling has been slow, octahedra.[*]

(*d.*) *Crystallizes also from solution in an essential oil,* by slow evaporation, and in dodecahedra, from solution of phosphuret of sulphur.

(*e.*) *Becomes covered with a brownish crust,* by keeping.

(*f.*) *Melts at* 99°, and this must be done always under water Volatilized at 219°, boils in close vessels at 554°, takes fire in the air, at 148°.[†]

(*g.*) *Highly inflammable, and burns with a bright white flame,* and much white smoke, which if collected is found to be acid.

(*h.*) *It burns with intense splendor in oxygen gas,* but the facts on this head are reserved for phosphoric acid. It burns also in chlorine and other gases, to be mentioned in their proper places.[‡]

(*i.*) *Burns slowly without flame;* in the dark, with a beautiful blue luminous cloud, and with a white smoke in the light; but not in air artificially dried; these appearances are more distinct, in proportion as the temperature is higher, and a garlic smell accompanies them. Mr. Boyle found that 3 grains emitted light for 15 days.

(*j.*) *A stick of phosphorus,* placed in a glass tube, for a handle, *will leave luminous traces,* if drawn on a wall in a dark room, but it does not show well unless in a warm place; in the cold, it is not apparent.

(*k.*) *A piece of phosphorus,* between two folds of paper, is easily inflamed by friction.

(*l.*) By means of a little tallow or wax, stick some *phosphorus* to the side of a wine glass, or tumbler, and it *may be inflamed by mixing sulphuric acid and water, in the vessel.*

(*m.*) *Phosphorus merely luminous does not burn the fingers,* still it is best always to take hold of it with forceps.

(*n.*) *Phosphoric fire bottles* are formed by putting very dry phosphorus into a dry vial with a small mouth, and then introducing a hot iron rod and rolling the vial upon it as an axis; it must be corked as soon as the iron is withdrawn.

---

[*] By melting and cooling large quantities under water, it has been obtained in octahedral crystals of the size of cherry stones.

[†] According to Higgins, if quite dry it takes fire at 60°. most authors say 108°, or 109.

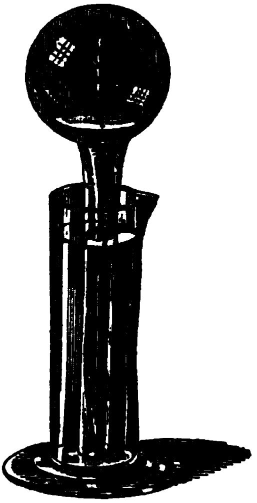
[‡] Mr. Graham has observed that its combustion is prevented by the presence of very small quantities of foreign gases and vapors, as 1-450th olefiant, 1-150th etherial vapor, 1-1820th vapor of naptha, 1-4444th of that of oil of turpentine, &c.—*Turner.*

(*o.*) The same thing is less perfectly done by simply melting the phosphorus in the vial and then corking and rolling it around, that the phosphorus may adhere to every part.

(*p.*) *A sulphur match is to be introduced and rapidly withdrawn,* rubbing at the same time against the side; if it does not fire, a little friction on a board or a cork will generally make it burn.[*]

(*q.*) *Eudiometry is performed by phosphorus,* by rapid combustion and by slow, in various ways.[†]

ATMOSPHERIC EUDIOMETER, BY PHOSPHORUS.—*Dr. Hare.*



"If a cylinder of phosphorus be supported upon a wire (as here represented) within a glass matrass, inverted in a jar of water, the oxygen of the included air is gradually absorbed. In order to determine the quantity of oxygen in the air, we have only to ascertain the ratio between the quantity absorbed, and the quantity included.

"This object may be attained by weighing the matrass, when full of water, and when containing that portion only which rises into it in consequence of the absorption. As the weight in the first case is to the weight in the last, deducting the weight of the glass in both cases, so will 100 be to the number of parts, in 100 of atmospheric air, which consist of oxygen gas.

---

[*] A spontaneous light is formed, by inserting a taper with a bit of phosporus on the wick, into a tube sealed and drawn thin at the end next the phosphorus; the other end may be sealed or not; the phosphoric end is heated in the mouth or otherwise, and withdrawn suddenly, or the tube is broken when the phosphorus fires—it is a toy.

[†] *Eudiometer of Seguin.*—Fill with and invert in mercury, a glass tube one inch in diameter and ten inches long; throw up a small piece of phosphorus; it is then melted by a live coal or hot iron, and small portions of a measured quantity of air are separately introduced; the phosphorus is inflamed each time; heat the top of the tube at finishing, and measure the residuum which is nitrogen.

Humboldt's.—Introduce phosphorus, 1 grain to 12 cubic inches of air, into a graduated tube, hermetically sealed at one end, and carefully corked at the other. Inflame it by a coal, and after all is cool the cork is withdrawn under water; the space unoccupied by the water is nitrogen gas.

Berthollet's.—In this there is a slow combustion, in a graduated glass tube. A measured quantity of air is thrown up, and a stick of phosphorus, supported on a glass rod, is made to pervade it. In a few days the oxygen gas will be absorbed, and an acid formed which will be absorbed by the water, while the nitrogen is left. Nitrogen gas dissolves a little phosphorus, and is thereby augmented in bulk about one fortieth, which must be in each case subtracted.

"If the neck of a vessel of this kind hold about one fourth as much as the bulb, by graduating the neck, so that each division will represent a hundredth part of the whole capacity, the result may be known by inspection."*

(*r.*) *Phosphorus is not luminous in oxygen gas*, and does not burn in it even slowly, nor can any light be perceived in the darkest place, *till the temperature is raised to* 80° *or* 81°, which, if the vessel is small, may be done by warming it by the hands.

(*s.*) *It then becomes luminous, and is surrounded by white vapors;* this appearance ceases again if the temperature sink to 55°; at about 104° it takes fire in oxygen gas; though not luminous at 55°, it appears to be dissolved slowly in the oxygen between that degree and 81°.

(*t.*) *If into oxygen gas thus impregnated with phosphorus, nitrogen or hydrogen be thrown up, it becomes luminous.*

(*u.*) Nitrogen dissolves phosphorus from 55° upward, and it may be distilled in this gas or in hydrogen, and it does not become luminous.

(*v.*) But a bubble or two of oxygen gas or common air, or any gas mixed with oxygen, renders the nitrogen luminous.

(*w.*) More strikingly still if phosphorized nitrogen be let up into such gases; pure oxygen is however best of all.

(*x.*) Phosphorus becomes luminous in common air, whose pressure is diminished to one eighth or one tenth that of the atmosphere.

(*y.*) Phosphorized nitrogen and phosphorized oxygen, (made by keeping both gases in contact with phosphorus for some hours,) do not become luminous when mixed at 55°.

(*z.*) *Phosphorus is* easily *dissolved, by simple digestion in oil of olives, almonds*, &c.

(*aa.*) Also, *in oil of turpentine* and other essential oils, but more care is necessary.

(*bb.*) Phosphorized oils rubbed on the face and hands,† or poured into hot water, exhibit luminous clouds and flashes.

(*cc.*) *Phosphorus dissolves in alcohol* with a gentle heat, but the experiment is dangerous, as the vial must be corked; it must therefore be very strong, and the heat applied very gentle.

(*dd.*) A flash of light appears when this spirit is poured upon hot water in the dark.

4. ELEMENTARY NATURE OF PHOSPHORUS.—*Sir Humphry Davy, by galvanizing phosphorus* in a glass tube, with a battery of 500 pairs

---

* For a more precise eudiometer see Dr. Hare's Compendium, p. 170.

† It should be ascertained that the phosphorus is all dissolved; otherwise severe burns may be produced.

of plates, *extricated a considerable quantity of phosphuretted hydrogen*, and caused the phosphorus to become of a deep red brown color. It is not, however, considered as certain that hydrogen is contained in phosphorus; it may, in this case, have proceeded from moisture accidentally present, for a little moisture would afford a large volume of hydrogen gas, which would of course be phosphorized.

5. Polarity.—Phosphorus is attracted by the negative pole in the galvanic circuit, and is therefore electro-positive.

6. Combining weight, 12.

7. Miscellaneous.—*Phosphorus exists no where in nature in a free state;* this would be impossible on account of its combustibility. It is found in the acid of the natural phosphates of lead, copper, iron, lime, &c.; most abundantly, however, in animal bodies, and more particularly in bones. It exists also in the saline form, in vegetable fluids. *Phosphorus is little used except in the laboratory. It is a violent poison*, even as is said, in the dose of 1 grain. In more moderate doses, it is stimulating, antispasmodic, &c. Its best form of exhibition is, dissolved in ether, 8 grs. to 1 oz. of which 4 or 5 drops containing about $\frac{1}{16}$ of a gr. may be given two, three, or more times in a day, in some spirituous tincture.—*Coxe.*

PHOSPHORIC ACID.

1. History.—Not known till after the discovery of phosphorus; observed by Boyle; first examined by Margraff.

2. Preparation.

(*a.*) *By decomposing bone ashes by sulphuric acid*, for the particulars of which process, see phosphate of lime.

(*b.*) *By the combustion of phosphorus.*—Phosphorus burning in an earthen dish floating on mercury is covered by a bell glass full of common air or oxygen gas.* The combustion in the latter, is rapid and brilliant, with much heat and light; the phosphorus with the oxygen is converted into phosphoric acid, which, in a dry vessel, is condensed in white flakes; the gas, if pure and in proper proportion, wholly disappears, and any foreign gas remains. There should be an excess of oxygen gas, to save the vessels from fracture; if the oxygen is pure at first, the remaining gas is still so.

---

* 500 grs. of phosphorus require 1 cubic foot of oxygen gas at a medium temperature for saturation, and the product is 1250 grs. dry phosphoric acid; 1 grain of phosphorus requires 15 cubic inches of common air, and of course about 4 cubic inches of oxygen for its saturation.—Note Book. Dr. Hope's Lectures, Edinb.

(*c.*) *This combustion is elegantly performed in a glass*[*] *globe*, of the capacity of three gallons, with a mouth two or three inches wide; a concave copper dish supported by wires which are hooked at the top so as to hang from the orifice, contains the phosphorus; a piece not larger than a hazle nut should be employed; the dry globe is filled with oxygen gas flowing from a gazometer and introduced by a tube going to the bottom and displacing the common air.

A hot iron kindles the phosphorus, and a saucer is laid over the orifice; when one piece of phosphorus is burnt out, another may be introduced through a glass tube, and will kindle of its own accord, and so on till the oxygen is exhausted.

This experiment, in one case, yielded me distinct crystals of perfectly transparent phosphoric acid, scattered in great numbers in the interior of the glass globe; they were not larger than a pin's head, and were formed from the viscous fluid arising from the deliquescence of flakes of concrete, snow-white phosphoric acid; when the air is admitted, it deliquesces in a few minutes.

(*d.*) The above experiment is neatly performed by commencing the combustion in a glass globe in common air or in oxygen gas, and allowing the last to flow in as it is needed, from a gazometer through a flexible tube; by introducing phosphorus and oxygen gas, alternately, the experiment may be safely continued as long as we please.

(*e.*) *Melt phosphorus in a thin glass globe under water, and inject oxygen gas through a tube, descending to the bottom of the vessel*, and connected with a bladder or gazometer; as the gas, by small portions at a time, comes in contact with the melted phosphorus, the latter flashes beautifully under the water, which dissolves the acid thus formed, and by evaporation, it is obtained solid.[†]—*Pelletier.*

(*f.*) *Drop successively, small pieces of phosphorus into warm nitric acid*,[‡] *diluted with an equal bulk of water*, contained in a flask, or tubulated retort. When the red fumes of nitrous acid gas cease, and the fresh pieces of phosphorus readily take fire at the surface, the process is through.

By continuing the heat, any remaining acid will be expelled, and the concrete phosphoric acid obtained; 1 dr. 3 grs. of phosphorus, with 3 oz. of the common acid, produce 6 dr. of phosphoric acid. The theory will be be given hereafter.

---

[*] See Lavoisier's Elements, and Dr. Hare's Compendium, p. 108, for an apparatus admitting of accuracy, in consequence of the use of the air pump.

[†] A considerable quantity of a red flaky substance floats in the water, which some have regarded as an oxide of phosphorus.

[‡] If the acid be concentrated, there will be a rapid inflammation, and if the pieces of phosphorus are large, there may be even a dangerous explosion.

Some writers recommend concentrated acid in a platinum capsule: this will ordinarily induce inflammation, or explosion, with some danger and considerable loss; with a diluted acid, in a mattrass, both inconveniences may be avoided. I have often tried both.

3. PROPERTIES.

(*a.*) Evaporated and *heated to ignition in a platinum crucible, it becomes white, firm and transparent, like glass.* This is the pure acid.*

(*b.*) *Deliquesces into a jelly;* soluble in water, *the anhydrous flakes dissolve with hissing;* the acid decidedly reddens the vegetable blues; it is very sour and almost corrosive; it combines with bases to form phosphates. It blackens oils.

(*c.*) *The glacial phosphoric acid is a hydrate,* and the water can not be expelled by heat, for if fully ignited, it rises in vapor with the water. It used to be said that this acid is fixed at intense degrees of heat; this remark applies only to the impure acid; still it endures a considerable heat, and from its tendency to vitrify with earthy bodies, *it is a powerful flux, and is very effectual in decomposing saline bodies, provided heat be applied.*

(*d.*) The deliquesced acid, on being heated in a platinum crucible, exhibits anew, after being cooled, the density and brilliancy of the precious stones.†

(*e.*) A great quantity of heat and light are liberated during the combustion, which unites two substances, one a gas, and the other a volatile odorous solid; the phosphoric acid is inodorous and fixed, and of great density, which implies great condensation. The dry acid sublimes in close vessels; a little water prevents this, but a larger proportion carries up some of the acid with it when it is evaporated.

(*f.*) A little heat is evolved when phosphoric acid of a spongy consistency, is mixed with water; the heat has varied from 1°, to more than 50°, as the density of the acid was greater or less.

(*g.*) Sp. gr. in glass 2.8516; in dryness 2.687; in deliquescence 1.417.

(*h.*) *Charcoal, at a red heat, completely decomposes the phosphoric acid;* carbonic acid gas is formed and the phosphorus sublimes, and may be received by immersing the neck of the retort under water. This is nearly the ordinary process for the extraction of phosphorus.

(*i.*) *Diamond* produces no effect; for it may be kept a long time in the midst of phosphoric acid, at a red heat, without experiencing any change; owing, without doubt, to the strong cohesion of its particles.*

---

* In the process by nitric acid, some ammonia is formed by the union of the hydrogen of the water with the nitrogen of the acid, and it is driven off by the heat.

† Chaptal says, "I observed once, to my great astonishment, that the phosphoric glass I had just made, emitted very strong electric sparks; these flew to the hand at the distance of two inches. I exhibited this phenomena to my audience of pupils. This glass lost the property in two or three days, though preserved in a capsule of common glass."

(*j*.) Phosphoric acid separates the carbonic, with effervescence, from its combinations.

4. Composition.—According to Lavoisier's elaborate experiments, related in his Elements, phosphoric acid is composed of about 60 parts of oxygen to 40 of phosphorus,† or about 3 parts of the former to 2 of the latter. Other and more recent philosophers give less oxygen, but differ in their results.

Rose,	100	phosphorus	are combined with	114.6	oxygen.
Dulong,	100	do.	do.	124.8	do.
Berzelius,	100	do.	do.	127.5	do.
Davy,	100	do.	do.	135.	do.

Davy formerly obtained 153. for the proportion of oxygen. Dr. Henry thinks that the true proportion is probably 133⅓. The combining weight of phosphorus has been deduced from the composition of phosphate of lead, and is taken at 12.‡ and that of phosphoric acid, adding 2 equivalents of oxygen, 16, at 28.

5. Polarity.—It is attracted to the positive pole, and is therefore *electro-negative.*

6. Uses.—A powerful acid, not known in common life nor in the arts. Some of its alkaline salts are used as fluxes.

7. Distinctive character.—The solid phosphoric acid, heated on charcoal by the blowpipe, exhibits a flame, proceeding from the decomposition of the acid by the coal and the consequent emission and combustion of phosphorus.

PHOSPHOROUS ACIDS.

1. History.—Lavoisier, in 1777, first demonstrated that the two acids of phosphorus, obtained by the slow and by the rapid combustion, are different compounds, owing to their different proportions of oxygen.

2. Preparation.

(*a*.) Till Sir H. Davy proved the contrary, it was thought that the only mode of preparing phosphorous acid, was by a slow combustion in the air. At a high temperature, phosphorus, whether burning in common air or in oxygen gas, is saturated with oxygen, and produces phosphoric acid; at a common temperature it becomes, at least in part, phosphorous acid.

---

* Fourcroy, II. 69.

† Corresponding, if phosphorus is 12, with 5 equiv. of each.

‡ For the grounds of this conclusion see Henry, Vol. I, p. 377, 10th ed. This number is not universally adopted. See Turner's Chemistry, 2d ed. p. 261, where it is stated that M. Dulong conceives the oxygen in the phosphorous and phosphoric acids to be in the proportion of 1.5 to 2.5 or 3 : 5, and Berzelius thinks that phosphoric acid is composed of oxygen 56 parts and phosphorus 44, (very near the results obtained by Lavoisier.)

(*b*.) Place sticks of phosphorus in a glass funnel, standing in the mouth of a bottle; a heavy acid vapor falls in a white current, and becomes liquid by deliquescence.*

The phosphorus is increased in weight, by that of the oxygen and water imbibed, and 1 part thus produces 3 or 4 of phosphorous acid. It is found, kowever, that the product is not, as was formerly supposed, phosphorous acid alone.

Sir H. Davy found it to be a mixture of phosphorous and phosphoric acids; but it is suggested by Murray that it is, when first formed, wholly phosphoric acid, but that in condensing it unites with more oxygen and becomes, in part, phosphoric acid. It appears probable that there is a definite compound of phosphorus and oxygen, forming phosphorous acid, although as obtained by deliquescence, the two acids are present in mixture.

3. PROPERTIES *of this mixed acid.*†

(*a*.) *A transparent dense fluid, viscid, adhering to the glass like oil,* but possessing various degrees of density as it has imbibed more or less water.

(*b*.) *It reddens dark vegetable colors, and sets the teeth on edge.*

(*c*.) *When heated,* a part of the water is evaporated, and it emits a white dense smoke, of an alliaceous odor, which in the open air, *takes fire with a vivid flash;* and the substance becomes entirely phosphoric acid.

(*d*.) This acid combines with water in every proportion.

(*e*.) Aided by heat, *nitric acid* readily *converts this acid into phosphoric acid*; proportions, 1 of the phosphorous acid, to 8 of the nitrous, of the sp. gr. 1.3. This is perhaps the best process for obtaining pure phosphoric acid.

USES IN MEDICINE, &c.—Valuable as a remedy against uterine hœmorrhage, in parturition.‡ Probably it would act also as a tonic.

OTHER MODES OF COMBINING PHOSPHORUS WITH OXYGEN.

(*a*.) Every person conversant with phosphorus must have observed that when it is kept immersed in water, the air not being entirely excluded, it is slowly oxygenized; and the water becomes acid.

---

* This simple arrangement is sufficient, but Fourcroy recommends to place the phosphorus in glass tubes, wide open at top, and capillary at the bottom; their points converge in the throat of a large glass funnel; they are thus secured from taking fire; the funnel is placed in a bottle, the bottle on a plate having water in it, and over the whole stands a glass receiver, with two apertures at its sides, to regulate the admission of the air; the bottom of the receiver is immersed in the water. This arrangement I have tried; it is neat and effectual, but more complex than is necessary.

† Dulong calls the acid thus obtained the *phosphatic*, regarding it as a distinct compound, (Phil. Mag. XLVIII, 273,) but this opinion is not generally adopted.

‡ Used by the late eminent Dr. Eneas Munson, of New Haven, who practised medicine with great success for 60 years. I used to supply him with this acid, and his language was, that it operated in such cases, *like a charm*.

(*b.*) The sticks of phosphorus are also covered with a white incrustation, which was formerly supposed to be an oxide of phosphorus.

(*c.*) If the phosphorus be at the same time exposed to the light, the incrustation becomes brown, water being decomposed, as is evinced by the evolution of phosphuretted hydrogen, and the formation of the phosphorus and phosphoric acids.*

(*d.*) When phosphorus is burned in less atmospheric air than is necessary to its entire consumption, there remains a red substance, supposed by some to be a hydrated oxide, but the exact composition of the oxides of phosphorus has not yet been ascertained. I have observed that the same substance is formed when phosphorus is burned in oxygen gas.

(*e.*) Phosphorus being burned in highly rarefied air, produces a "red solid, comparatively fixed, and requiring a heat above 212° for its fusion—a white, and easily volatile substance, which is combustible, soluble in water, and has acid properties, and a substance, which is strongly acid, and not volatile, even at a white heat.† The first appears to be a mixture of unburned phosphorus, and phosphorous acid; the second to be phosphorous acid; and the third to be phosphoric acid."‡

The white volatile solid unites with bases, and forms salts, that are called phosphites. This acid absorbs oxygen from the air, and becomes phosphoric acid, and on account of its avidity for oxygen, it precipitates the salts of mercury, silver, platinum and gold.

PHOSPHOROUS ACID OF DAVY.

Remark.—According to Sir H. Davy, as already stated, what has been usually called phosphorous acid, is a mixture of the phosphorous and phosphoric.

1. Preparation.

(*a.*) *Sublime phosphorus through corrosive sublimate*, and a limpid fluid is obtained, a compound, as is supposed of chlorine and phosphorus.

(*b.*) Mix this product with water, and apply heat till the liquid is of the consistence of syrup; it is said to be a solution of pure phosphorous acid in water, and it becomes solid and crystalline on cooling. The theory will be intelligible after chlorine has been discussed.

---

* I have a bottle of sticks of phosphorus which were put up for me in London, 25 years ago. Having been distilled in hydrogen gas, they were then white, but they are now covered by a lively red crust, and the water, which has never been changed, is decidedly acid.

† According to the views now entertained of the pure glacial phosphoric acid, it should be volatilized at a lower heat than that stated in the text, on the authority of Sir H. Davy.

‡ Henry, 10th Ed. Vol. I, p. 371.

2. **Properties.**

(*a.*) *Acid to the taste—reddens vegetable blues*, and forms phosphites with alkalies.

(*b.*) *Odor fetid—give white vapors by heat*—combustible in the air, and therefore contains an excess of phosphorus, which being expelled or burned, the residuum is phosphoric acid.

3. **Composition.**

Phosphorus, - -	56.81	100	132
Oxygen, - - -	43.19	76	100
	100.00*		

Phosphorus, - -	56.524	100
Oxygen, - - -	43.476	76.92
	100.†	

By a more recent investigation, Sir H. Davy concluded that phosphorous acid contains just half as much oxygen as phosphoric acid.

Phosphorus, - -	59.7	100.
Oxygen, - - -	40.3	67.5
	100.	

4. **Constitution.**—Taking it for granted, that in phosphorous acid, the elements are united, equivalent and equivalent, and calling phosphorus 12; the phosphorous acid will be represented by 12+8 =20, the representative number,‡ while phosphoric acid is supposed to be composed of phosphorus, 1 equivalent, 12, and oxygen, 2 equivalents, 16=28, as stated under phosphoric acid.

The above are the views of Sir H. Davy and Dr. Thomson, but Berzelius and Dulong consider the oxygen in the two acids as being in the proportion of 2 to 5.

HYPO-PHOSPHOROUS ACID.

1. **History.**—*Discovered by Mr. Dulong*,§ in consequence of observing the peculiar action of phosphuret of baryta upon water.

2. **Preparation.**

(*a.*) *By this action, two compounds are said to be formed; an insoluble phosphate* of the earth easily separable by the filter.

(*b.*) *A soluble barytic salt* which passes through the filter.

---

* Gay-Lussac. † Dulong, Phil. Mag. XLVIII, 273.

‡ Henry, Vol. I, p. 373, 10th Ed. § Phil. Mag. V. 48, p. 271.

(*c.*) *Decompose the latter by* just so much *sulphuric acid*, as precipitates the earth.

(*d.*) *An acid solution remains*, which, after evaporation, is viscous, tenacious, and uncrystallizable.

(*e.*) *By a stronger heat, phosphuretted hydrogen gas is expelled*—phosphorus sublimed and phosphoric acid remains.

3. Properties.

(*a.*) *Forms with alkaline and earthy bases, salts of extreme solubility.*

(*b.*) Those of baryta and strontia, crystallize with great difficulty.

(*c.*) Those of the alkalies are soluble in all proportions, in highly rectified alcohol.

(*d.*) That of potassa is more deliquescent than muriate of lime.

(*e.*) *Absorb oxygen slowly from the air*, and by heat applied in a retort, give the same products as the acid itself.

4. Composition.—Phosphorus, 72.75 100.
Oxygen, 27.25 37.44

100.

Calculated by Dulong, upon the supposition that it is a binary compound of oxygen and phosphorus, but it may be a triple compound of these two, and hydrogen forming an *hydracid*; in which case, its proper name would be *hydro-phosphorous acid.* Sir H. Davy thinks that the oxygen of this acid is just half that of phosphorous acid, and of course that 100 of phosphorus are combined with 33.75 oxygen. If, as above stated, phosphorous acid consists of an equivalent of each element, it is probable that this acid contains two equivalents of phosphorus, $12\times2=24+1$ of oxygen, $8=32$, its representative number.* It is not certain that we are yet accurately acquainted with the proportions of the elements in the acids of phosphorus.

PHOSPHATES.

General Characters.

(*a.*) Phosphates of alkalies partially decomposed by ignition with charcoal; phosphate of ammonia is decomposed by heat alone.

(*b.*) Phosphates of the alkaline earths not decomposed when heated with charcoal, nor is phosphorus obtained.

(*c.*) Before the blowpipe, both alkaline and earthy phosphates, melt into a vitreous globule, sometimes transparent and sometimes opake; that of ammonia is dissipated entirely.

---

* Henry, Vol. I, p. 374, 10th Ed.

(*d.*) Soluble in nitric and phosphoric acid, without effervescence, and precipitated from that solution by lime water or ammonia.

(*e.*) Sulphuric acid decomposes them, at least in part, and separates the phosphoric acid.

(*f.*) Often phosphoresce by heat.

(*g.*) Form bi-phosphates and some triple salts.

(*h.*) Those of the alkalies, soluble; of the earths, insoluble.

PHOSPHATE OF POTASSA.

1. PREPARATION.

(*a.*) In the mode soon to be mentioned for the phosphate of soda.

(*b.*) By heating the bi-phosphate in a platinum crucible, along with pure potassa.

2. PROPERTIES.

(*a.*) Insoluble in cold, but soluble in hot water; "it precipitates as the solution cools in a brilliant gritty powder." Very fusible—producing before the blowpipe a transparent bead—opake on cooling, Forms a "thick, glutinous and adhesive" solution in muriatic, nitric, and phosphoric acids; alkalies occasion no precipitate from these solutions, if much diluted; otherwise, the reverse.

The vegetable grains belonging to the *Cerealia*, contain a small quantity of this salt.

It is supposed to be a compound of 1 equivalent of water, 2 of acid, and 1 of alkali.

It is said that a *subphosphate of potassa* is obtained by fusing potassa and phosphate of potassa together, in a platinum crucible.

It is insoluble in cold, but sparingly soluble in hot water. It is supposed that it has two equivalents of potassa and 1 of acid, while the neutral phosphate contains one equivalent of each constituent, and the bi-phosphate, 2 of acid to 1 of alkali.

BI-PHOSPHATE OF POTASSA.

1. PREPARATION.—*Formed by dropping liquid phosphoric acid into carbonate of potassa,* till effervescence ceases, and the liquid ceases to precipitate muriate of baryta.

2. PROPERTIES.

(*a.*) *By evaporation crystallizes in square prisms;* the primary form, an octahedron with square bases. The composition is, 1 equivalent of potassa, 2 of phosphoric acid, and 2 of water.

(*b.*) *Very soluble in water;* taste bitter; sp. gr. 2.8516; by heat, melts and loses its water; becomes dry, and again deliquesces. At ignition, melts into a transparent deliquescent glass. Exists in small quantities in barley.*

---

* Hope. Note Book.

PHOSPHATE OF SODA.

Dr. Pearson, of London, introduced it into medicine, and his process for forming it, is as follows—

1. Preparation.

(*a.*) To a solution of 1400 grs. crystallized carbonate of soda, at 150°, in 2100 grs. of water; add by degrees, 500 grs. phosphoric acid of the sp. gr. 1.85; boil, filter while hot, and crystals will continue to form for several days. From the above quantity of materials, Dr. Pearson obtained from 1450 to 1550 grs. of crystals.

(*b.*) The usual process is to add carbonate of soda in excess, to the impure phosphoric acid,* procured from the decomposition of bone ashes by sulphuric acid. (See phosphate of lime.) The solution is filtered, and crystals are obtained by slow evaporation.†

2. Properties.

(*a.*) *The phosphate of soda of the shops has an excess of alkali*, which is said to be essential to the formation of good crystals; they are rhomboidal prisms, with pyramidal terminations, and their solution turns blue vegetable colors green.

(*b.*) Its taste is much like that of common salt.

(*c.*) From this circumstance, *it is advantageously employed as a purgative*, as it may be taken in broth, &c. without disgust, and even without the patient's knowledge. Dose, from six drachms to one ounce.

(*d.*) *Soluble in about 4 parts of water*, at 60°, and in 2, at 212.

(*e.*) *Suffers the aqueous fusion*, and loses .62 of water, dries, and melts at a red heat; by cooling after blowpipe fusion, assumes a polyhedral form.

(*f.*) *Effloresces rapidly* on the surface.

(*g.*) *The strong acids decompose it partially*, and the free phosphoric acid forms a very soluble bi-phosphate.

(*h.*) With most of the earths, fuses into vitreous compounds, being *an excellent flux.*

(*i.*) In the humid way, baryta, strontia, and lime, attract its acid; it is doubtful whether potassa decomposes it.

3. Composition—of the dry salt.

Phosphoric acid, - -	53.48	100
Soda, - - - - -	46.52	
	100.00‡	

---

* Holding phosphate of lime in solution, which is precipitated.

† For processes, vide Black's Lectures, Vol. II, 233 and 4.

‡ Berzelius, Ann. de Chim. et de Phys. II, 164.

Dry phosphoric acid,	1 equivalent,	28	or 46.67
Soda, - -	1 "	32	or 53.33
	Its equivalent,	60	100.00
In crystals ; Phos. acid,	1 equivalent,	28[*]	16.39
Soda,	1 "	32	18.73
Water,	12 "	108	64.88
	Its equivalent,	168	100.00[†]

According to Mr. Dalton's opinion, the salt above described is a bi-phosphate, having 2 atoms of acid, and 1 of base, with double the acid, making a *quadro-phosphate*—it is neutral as to test colors.

To render the common or bi-phosphate neutral, Mr. Dalton says that its soda[‡] must be doubled, when it will acquire much more solubility, and crystallize in fine needles.

Mr. Dalton recommends this form of the salt as a test. Dr. Henry remarks, that fresh experiments are necessary to reconcile these discordant statements.[§]

By heat on a sand bath, the crystals loose 12 equivalents of water, without changing their properties. It is said that they still retain ½ an equivalent of water, which they give up at ignition; and then being redissolved in water, and the solution spontaneously evaporated, irregular four sided prisms are obtained, whose primary is a rhombic octahedron; they do not effloresce, are much less soluble than before, and consist of 1 equivalent of acid, and 1 of soda, with 5 of water. The solution precipitates nitrate of silver, white, and not yellow, like the common phosphate. A phosphate of soda has also been obtained, from a solution evaporated at 90°, containing 7½ equivalent of water; they are permanent in the air, and have a different form from the common phosphate.[‖]

4. Miscellaneous.

(*a.*) *Exists in human urine, with phosphate of ammonia* and, the concrete salts, obtained by evaporation, are principally these two; formerly, under the name of *microcosmic salt*, much employed as a flux, with the blowpipe.

(*b.*) *The phosphate of soda is used* for the same purpose, and besides its use in medicine, it is advantageously employed *as a substitute for borax* in the soldering of metals.

(*c.*) It is useful in chemistry; by double exchange, we can thus form almost all other phosphates.

---

[*] 35.71, Mitscherlich, quoted by Turner, 2d Ed. p. 581.

[†] Thomson's, First Prin. I, 201.

[‡] By adding as much again caustic soda.

[§] Turner, Vol. I, p. 568.

[‖] Turner, 2d Edition, p 281, and Edin. Jour. XIV, No. p. 298.

PHOSPHATE OF AMMONIA.

1. **Preparation.**

(*a.*) *By saturating pure phosphoric acid with ammonia.*

(*b.*) By decomposing, by carbonate of ammonia, the acidulous liquor proceeding from the action of sulphuric acid upon bone ashes. (See phosphate of lime.)

2. **Properties.**

(*a.*) *Its crystals are rhombic prisms*, terminated by dihedral summits; the primary form is an oblique rhombic prism, whose smaller lateral angle is 84°, 30′; sometimes it is obtained in needles.

(*b.*) *Its taste is sharp*, cooling, and ammoniacal.

(*c.*) Sp. gr. 1.8051.

(*d.*) *Soluble in 4 parts of water at* 60°, and in less at 212°; crystallizes on cooling, but not beautifully, unless by spontaneous evaporation.

(*e.*) Not affected by the air.

(*f.*) Suffers the aqueous fusion, and *is decomposed by heat;* the ammonia is exhaled, *and the phosphoric acid melts into a vitreous globule.*

(*g.*) *This is one mode by which the phosphoric acid is obtained pure, or nearly so.*

(*h.*) On account of the facility with which this salt is decomposed by heat, *it affords phosphorus when heated with charcoal.*

3. **Composition.**—Acid 28+17 ammonia, or 62.22, and 37.78. There is said to be also 1½ equivalent of water.*

4. **Miscellaneous.**

(*a.*) *It exists in urine, mixed with the phosphate and muriate of soda*, from which it is difficult to free it; in that state it forms the long famed *microcosmic salt.*

(*b.*) *In its pure state not employed;* but the microcosmic salt has been much used as a flux for the mineralogist, and in the composition of the pastes.

BI-PHOSPHATE OF AMMONIA.

1. **Preparation.**—*By adding to phosphoric acid, ammonia or its carbonate*, till the solution ceases to precipitate muriate of baryta.

2. **Properties.**—*Less soluble than the natural phosphate;* no change in the air; primary form, an octahedron, with a square base, but the right square prism, with a rhombic base is most frequent.†

3. **Composition.**—Acid, 2 equivalents, 56+2 of ammonia, 34 +3 of water, 27=117 for its equivalent.

---

* Turner, quoting Mistcherlich.

† Turner.

PHOSPHATE OF SODA AND AMMONIA.

1. **Preparation.**—*By dissolving in a little boiling water,* 1 *equivalent of muriate of ammonia, and* 1 *of phosphate of soda;* the double phosphate crystallizes as the fluid cools, and muriate of soda remains in solution.

2. **Properties.**

(*a.*) *Primary form, the oblique rhombic prism;* effloresces, losing ammonia, and passes to the condition of bi-phosphate of soda.

(*b.*) *Decomposed by heat;* the ammonia and water are dissipated and a very fusible bi-phosphate of soda remains.

3. **Composition.**—1 equivalent phosphate of soda, 60,+1 of phosphate of ammonia 45,+10[*] of water in the crystals=90=195.

Remarks.—This is the microcosmic salt, in a state of purity. According to Fourcroy, this salt effloresces, loses its ammonia, and passes to the condition of bi-phosphate of soda. It turns tincture of violets green. The ammonia is said to be dissipated by repeated solutions and crystallizations.

PHOSPHATE OF LIME.

1. **Discovery.**—*By Gahn and Scheele, in* 1774, *who found that bones consist principally of this substance,* with some other salts, cemented by gelatine; it exists in bones, in the proportion of 86 per cent.

2. **Preparation.**

(*a.*) By precipitating lime water, by liquid phosphoric acid—

(*b.*) Or, phosphorus burned beneath a bell glass inverted over lime water, becomes phosphoric acid, and precipitates the lime—

(*c.*) Or, *by mingling solutions of phosphate of soda, and muriate of lime,* adding the muriate last[†]—

(*d.*) *Or, we may purify the phosphate of lime of bones*—or, lixiviate bone ashes with abundance of hot water, to remove muriate and phosphate of soda, and the carbonate of lime may be dissolved by acetic acid; or, dissolve the phosphate by muriatic acid and precipitate by ammonia; the phosphate falls without decomposition, and after being dried is pure.[‡]

3. **Properties.**

(*a.*) *A white powder, never crystallized except as a native mineral.*

(*b.*) Insoluble in water, tasteless and inodorous.

(*c.*) *Melts by the most intense heat into an opake white enamel.*

(*d.*) Unaffected by the air.

(*e.*) Formed with water, into a paste, *it is made into cupels for the assayers.*

---

[*] Mitscherlich quoted by Turner.

[†] Otherwise the precipitate will have excess of base, and the liquor will be acid. —*Berzelius.*

[‡] Fourcroy.

(*f.*) ***Partially decomposed by acids***, especially the stronger, and even by the vegetable acids.

4. Composition.—One equivalent of acid, 28, and one of lime, 28.

Bi-phosphate of lime is easily formed by dissolving phosphate of lime in as much phosphoric acid as the salt contains, and it is always formed, (or at least a phosphate with excess of acid,) in the decomposition of bone ashes, as will appear more particularly farther on. The bi-phosphate is very soluble in water and does not crystallize.* It melts before the blowpipe into a transparent globule; it is insoluble, and doubtless, by the heat, loses the excess of acid.

Remark.—For a notice of Mr. Dalton's views respecting the bi- tri- quadri- octo- and dodeca-phosphate of lime, containing, as is supposed, 2, 3, 4, 8 and 12 equivalents of acid, reference may be had to Henry's Chemistry, 10th ed. Vol. I, p. 591.

5. Mineral and animal phosphate.

Found as a mineral in many countries; in Estremadura, in Spain, forms extensive rocky strata; it is there used in building. Most of the natural phosphates are highly phosphorescent by heat; animal phosphates are not. Occurs crystallized in Saxony, Bohemia, England, United States, &c. in six sided prisms and tables; it is called *apatite and asparagus stone.*

It exists in most animal fluids; in human urine, in the form of bi-phosphate, and is precipitated by lime water and the alkalies; in milk and blood; it is found in the muscles and in jelly; in preternatural ossifications, and in most of the calculi, whether in the kidneys or the bladder. It exudes through the skin, and is found in the solid excrements of animals whose urine does not contain it. It is found also in the ashes of both vegetable and animal substances.

6. Process for phosphorus.†

(*a.*) ***Burn bones in a furnace, or even in a common fire;*** the oils, gelatine, &c. will be consumed and the osseous part will be easily pulverized. In an earthen pan or dish, place bone ashes 2 parts, water 20 and sulphuric acid 1;‡ digest them upon embers or by a sand heat, and stir thoroughly, with a glass rod during ten or twelve hours; throw the mass upon a coarse linen filter, stretched over a frame with tenter hooks; wash the insoluble residuum with boiling water till it comes off tasteless; the fluid will be turbid; let it settle, and then draw it off clear; evaporate in a clean copper or tin vessel to dryness; or, it will answer if still moist.

---

* Fourcroy says it can be made to crystallize in brilliant micaceous scales.

† For a series of years, I was in the habit of manufacturing all the phosphorus required in the experiments of the laboratory, and nearly every part of the annexed statement I have repeatedly verified by my own experience.

‡ There will be a considerable effervescence owing to carbonate of lime, and as is said, carbonate of soda.

(*b.*) *The fluid obtained by the filtration is acidulous phosphate and acidulous sulphate of lime;*[*] the two neutral salts being held in solution by an additional quantity, probably an equivalent of their respective acids. To free the fluid from the earthy matter thus dissolved, the liquor may be decomposed by acetate or nitrate of lead, and the precipitate of phosphate of lead may be decomposed by heating it in an earthen retort, with half its weight of charcoal powder. The phosphorus, obtained in this way, may be contaminated with sulphur, because sulphate of lead is thrown down by the acetate or nitrate; this may be got rid of, by decomposing the phosphate of lead by sulphuric acid, and then the liberated phosphoric acid by charcoal.

(*c.*) *This process is complicated, and it is better to decompose the acidulous phosphate by adding carbonate of ammonia;* the phosphate of ammonia, on being evaporated and heated to low redness, gives up its ammonia; sulphate of ammonia, if present, is volatilized, and the phosphoric acid is obtained nearly or quite pure. But even this is unnecessary, if the object is merely to obtain the phosphorus; for that purpose the acidulous phosphate may be at once decomposed.

(*d.*) *The purified acid, mixed with one half its weight of charcoal powder and heated in a furnace, affords about one fourth of its weight of phosphorus.*[†]

(*e.*) *The solid residuum from* (*b*) *is commonly employed to afford phosphorus.*

(*f.*) *It is mixed with from* $\frac{1}{4}$ *to* $\frac{1}{2}$ *its weight of dry powdered charcoal and distilled.*

(*g.*) The acidulous solution, when considerably evaporated, must be suffered to cool, and sulphate of lime will subside, which must be separated.

(*h.*) *The earthen retort is glazed with lime,* 1 *part, slacked with a solution of* 2 *parts of borax;* and with this mixture the retort is washed thoroughly, inside and out; when it is heated it will melt and fill the pores through which the phosphorus would otherwise escape.

(*i.*) *The retort is carefully coated with fire lute, and its neck dips into water;* the heat is very gradually raised, and much gas is produced; it burns spontaneously, with brilliant flashes; we continue the heat some time after gas has ceased to come.

(*j.*) If the neck of the retort is choked, which is ascertained by a wire, a hot iron bar is applied to it externally to melt the phosphorus.

(*k.*) *Some phosphorus may come over into the water, but most of it condenses in the neck of the retort,* and must be got out by heating it with water poured from a tea kettle.

---

[*] Perhaps bi-phosphate and bi-sulphate.

[†] It is said not to be so good for this purpose as the acidulous phosphate, because it is more liable to be volatalized.

(*l.*) *Phosphorus is purified by straining it through leather under hot water;* or better by distillation in vessels filled with hydrogen gas. It is melted under hot water, in a retort, and suffered to congeal; the retort is then filled with hydrogen gas, its mouth plunged into warm water, and the distillation is performed by a sand heat or even by a naked fire: it is a delicate and difficult process; I have been successful with it, but have had the retort break from the regurgitation of the water; in such a case there is a violent and even dangerous combustion.

(*m.*) *It is cast into sticks in the throat of a funnel, or drawn up into tubes by suction;* the finger, protected by leather, is slipped over the end of the tube, and the latter is then placed in cold water.

(*n.*) *Phosphorus may be obtained by precipitating the phosphoric acid from urine, or from phosphate of soda, by nitrate or acetate of lead;* we distil the concrete residuum with charcoal. About 14 or 18 parts of phosphorus are afforded by 100 parts of phosphate of lead; less heat is necessary in this than in the process with bones.

(*o.*) *The product of phosphorus is greatest when the materials are dry and the distillation is slow.* Pelletier obtained 60 ounces at one operation, from the acid of 36 lbs. of bones, (576 ounces,) decomposed by 30 lbs. of sulphuric acid; at another time he procured only half this quantity.

(*p.*) *Phosphorus is purified by liquid chlorine.* It should be previously granulated, which is done by melting it beneath water and shaking it as the water cools; then by shaking it in solution of chlorine the color is in a few minutes removed.*

PHOSPHATE OF BARYTA.

1. Preparation.—*The muriate or nitrate of baryta, mixed with the phosphate of soda or ammonia,* produces a precipitate of phosphate of baryta.

---

* By estimates made thirty years ago, the acids which decompose the phosphate of lime, take up no more than $\frac{16}{100}$ of the lime it contains, and separate from it less than half the phosphoric acid; "100 parts, treated by an acid, afford only .33 of acidulous phosphate of lime, containing only .17 of disengaged phosphoric acid out of the .41 of this acid which exists in the 100 parts of phosphate of lime; so that by the distillation of this substance with charcoal, we obtain only about .05 of phosphorus, instead of .16 which exist in the 100 parts of the bases of bones." It would seem, however, (*o.*) that Pelletier obtained double this quantity. Neutral phosphate of lime remains in the retort after the distillation of phosphorus; its origin is obvious. We decompose no more phosphoric acid than what goes to hold in solution the phosphate of lime. In the process of the older chemists, the solid extract of urine was distilled to obtain phosphorus; only the phosphoric acid of the phosphate of ammonia was decomposed by the combustible matter present, and therefore very little phosphorus was obtained; the product is increased by the addition of charcoal.

2. **Properties.**—White, insipid, pulverulent, insoluble in water, soluble in nitric and muriatic acids; applied to no use.

3. **Its composition**, after being washed and dried, is, according to Berzelius—

Phosphoric acid, - - - -	31.8	100.
Baryta, - - - - - -	68.2	214.46
	100.	

Dr. Henry suggests that if it be constituted of 1 equivalent of acid and 1 of base, its composition will be expressed by

Phosphoric acid, - -	28	26.62	100
Baryta, - - - - -	78	73.38	280
Its equivalent,	106	100.00	

Berzelius, by dissolving baryta in phosphoric acid, and evaporating the solution, obtained acidulous crystals, which, if composed of 2 equivalents of acid, =56, and 1 of base, =78=134, and would be a *bi-phosphate.* From a solution of these crystals, alcohol precipitates a bulky white and tasteless substance, which appears to be composed of 2 equivalents of base, and 3 of acid, or if we say 1 of the former and 1½ of the latter, it would be called a sesqui-phosphate.*

PHOSPHATE OF STRONTIA.

1. **Formation and properties.**—Every thing in the last article is applicable to this, except that it is soluble in phosphoric acid, gives a purple flame with charcoal before the blowpipe, is totally decomposed only, by the sulphuric acid and partially by the nitric and muriatic acids. It is fusible by the blowpipe, into a white enamel; it is soluble in 2000 parts of water.

2. **Composition.**—Acid, 36.565, base, 63.435=100.00.

Dr. Henry remarks, that "if a true binary compound, it should consist of very nearly 65 base, + 35 acid; and that there is a *bi-phosphate* consisting of 2 atoms of acid, 1 atom of base, and 2 of water."

PHOSPHATE OF MAGNESIA.

1. **Preparation.**

(*a.*) *By digesting phosphoric acid on magnesia or the carbonate.*

(*b.*) *By mixing equal quantities of the concentrated solutions of sulphate of magnesia and phosphate of soda;* in a few hours, crystals of phosphate of magnesia are formed.

---

* Henry, Vol. I, p. 605. See Berzelius on two sub-phosphates, Ann. of Phil. XV, 277.

2. **Properties.**

(*a.*) *They are compressed prisms;* speedily effloresce and require 15 parts of cold water for solution; hot water dissolves so much that crystals form as the solution cools.

(*b.*) Lose water of crystallization by heat; melt by a still higher heat into a glass.

(*c.*) *Decomposed entirely by* sulphuric, nitric, and muriatic *acids*, and by *fixed alkalies and alkaline earths.* Ammonia forms a triple salt, which exists in urine.

(*d.*) Composed of acid, 1 equivalent, 20; base 1, 28=48, and when crystallized, water 7=63=111.—*Thomson.*

PHOSPHATE OF AMMONIA AND MAGNESIA.

1. **Discovery.**—*Found by Fourcroy, in the calculus of a horse;* exists in the bones of most animals, and is common in the human subject.

2. **Preparation.**

(*a.*) *Formed by adding phosphate of ammonia, or ammonia, or its carbonate to phosphate of magnesia;* or carbonate of ammonia and afterwards phosphate of soda to solution of sulphate of magnesia, when the double phosphate subsides in the form of minute grains.

(*b.*) *Magnesia is detected* when in solution in an acid, with or without other earths, *in the following manner.*

(*c.*) *Add to the solution bi-carbonate of ammonia,* (formed by exposing common carbonate to the air, till it has lost its smell;) *the other earths will be precipitated, but not the magnesia.*

(*d.*) *Add a cold saturated solution of phosphate of soda; a white powder precipitates which is the ammoniaco-magnesian phosphate.*

(*e.*) *Ammoniacal phosphate of magnesia* is a white powder which lines the cavities of some calculi in the form of crystals, and *is frequently deposited in crystals.*

(*f.*) *Tasteless, insoluble in water, soluble in acids,* even in the acetic, and is precipitated unchanged when the acid is saturated by ammonia; decomposed by heat, the ammonia and water flying away, and leaving the phosphate of magnesia; composed of equal weights of phosphate of ammonia, phosphate of magnesia, and water.*

PHOSPHATE OF ALUMINA.

Phosphoric acid combines with alumina, to saturation, forms a white insipid powder which melts before the blowpipe into a transparent globule.

* * * * * *

The phosphates of the other earths are comparatively unimportant.

---

* Its composition is said to be otherwise not accurately determined. Stromeyer states the magnesia at .37.—*Turner.*

But Thomson states it at 1 equiv. phosphate of magnesia, 48, 1 equiv. phosphate of ammonia, 45, 4 of water, 36; its equivalent being 129, the salt being dried without heat.

BINARY COMPOUNDS OF PHOSPHORUS WITH VARIOUS BASES.

PHOSPHURETTED HYDROGEN.*

1. PREPARATION.

(*a.*) Hydrogen gas may be partially phosphuretted, by heating phosphorus in it by the solar rays.

(*b.*) The better mode is to *heat a strong alkaline solution*, (potash or soda,) *with phosphorus;* the retort may be previously filled with hydrogen gas.

(*c.*) To do this properly, introduce the phosphorus and fill the retort with hot water—as it cools, the phosphorus will congeal, and adhere to the bottom, so that it will not fall out; throw in the hydrogen gas by means of a bladder and tube, or by a tube coming from an air jar, or a gazometer; keep the mouth of the retort down, and with the finger upon it, dip it into the alkaline solution; now expel so much gas, by warming the retort, that when it cools, the requisite portion of fluid may enter.

(*d.*) Or, fill the retort with the alkaline solution, and throw out by hydrogen gas, as much as you choose.†

(*e.*) Or, we may mix *lime with a strong solution of pearl ashes and add the phosphrous;* or, *use solution of caustic potash, phosphorus, and quick lime; or quick lime only, and phosphorus, and water.* Either of these methods will succeed. The first and the last of the three now named, are easy and cheap, and answer as well as the more troublesome modes usually described; the last process, which is the easiest, is little inferior to any other. In all cases, it would be better to wait till ebullition, when the vapor will have expelled the air; then through the tubulure of the retort, drop in the phosphorus; this saves the necessity of any other precaution.

(*f.*) *Phosphuret of lime, with dilute muriatic acid, and a moderate heat;* to prevent explosion, the retort may be entirely filled with the diluted acid.

---

* Discovered in 1783, by Gengembre. It is called also phosphuretted and biphespuretted hydrogen gas.

† My method is to fill a small retort, (holding from 4 to 6 or 8 oz.) with a strong alkaline solution. Drop in the phosphorus, then from a small vial with a bent tube and a little iron filings and diluted acid, throw up as much hydrogen gas, as will displace the greater part of the fluid, keeping the mouth of the retort in a bowl of the same solution, then place the neck of the retort under the shelf of the tub, and apply a lamp. It never fails. A bottle full of the solution will last for years, as but little is expended at a time.—*Communicated*, J. G.

I would add, that even when the air is not removed, the only precautions necessary to be observed, are—not to immerse the beak of the retort until it has ceased flashing in the interior, and begins to shew flame at the mouth—not to immerse it deeply at all, and to watch that the water does not go back by regurgitation.—*Author*.

In these cases water is decomposed; its hydrogen, with a portion of phosphorus, forms phosphuretted hydrogen, and its oxygen, with other proportions, forms phosphorous, and hypo-phosphorous acid.

2. Properties.

(*a.*) *Smell alliaceous; fires spontaneously, with a beautiful ring of smoke, rising and enlarging for some distance;* it is vapor of water and phosphorous-acid; similar appearances are sometimes seen during the discharge of artillery.

(*b.*) *Detonates with oxygen,* 1½ *of oxygen to* 1 *measure of phosphuretted hydrogen;* only one bubble of either gas must be let up into the other at once. The combustion is very brilliant.* If only 1 measure of oxygen be used, the product is phosphorous acid, if 1½, it is the phosphoric.

(*c.*) *In chlorine and nitrous oxide gases, phosphuretted hydrogen explodes.* In all these cases, the same effect is produced, if the gas supporting combustion be let up into the phosphuretted hydrogen, and with oxygen this course is rather safer.

(*d.*) Sulphurous acid gas, and phosphuretted hydrogen mutually decompose each other.

(*e.*) *Phosphuretted hydrogen loses its spontaneous inflammability, after standing* a short time; a part of the phosphorus is deposited; but it still burns, and with a very bright light, when kindled by a candle.

(*f.*) *In the dark,* and over mercury, *it retains its inflammability* a long time.

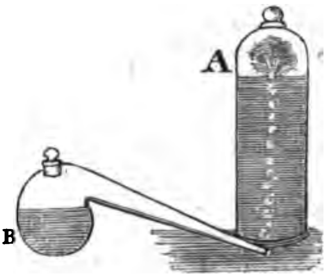
(*g.*) *It is lighter than common air.* Air being 1, its sp. gr. is according to Thomson, .9027, theory and experiment coinciding, for

sp. gr. of hydrogen, - - - - - 0.0694
And of phosphorus vapor, 0.8333
0.9027†

Dumas gives it at 1.761; Dalton at 1.1.

---

* A, represents an air jar, with a few cubic inches of oxygen gas, standing over a column of water. B, is a retort, with slacked lime, phosphorus, and strong solution of pearl ashes, the bubbles of gas coming singly, but rather rapidly—on depressing the mouth of the retort, (on a particular occasion,) a little gas accumulated, and one bubble hung in the glass jar without explosion, but the next blew up the whole with great violence, broke all the contiguous glass vessels, shot some of their fragments to the distance of 40 feet, among a large audience, and slightly wounded several spectators; this shews the necessity of extreme caution.—See Am. Jour. Vol. VI, p. 187.



† Henry, Vol. I, p. 489.

(*h.*) *Water absorbs a portion of this gas, by agitation*; if thoroughly deprived of air at 55°, it absorbs $\frac{1}{8}$ of its bulk, (Dalton;) $\frac{1}{28}$ (Thomson.)

(*i.*) Heat, below boiling, expels it unaltered and inflammable.

(*j.*) *Spontaneously decomposed by exposure to the air;* oxide of phosphorus is precipitated, and the gas rises uninflammable, (spontaneously.)

(*k.*) *Solution of this gas does not change the test colors.* This gas being readily absorbed by sulphate of copper, and chloride of lime, a sure method is thus afforded of ascertaining whether it is contaminated with common hydrogen.

(*l.*) *Precipitates many metallic solutions* in the state of phosphuret.

(*m.*) *Potassium does not inflame in phosphuretted hydrogen gas*, even when heated, but the potassium is converted into a phosphuret, and 2 measures of the gas become 3.

(*n.*) *Decomposed by heat*, by electricity, and by vaporizing sulphur through this gas; it then becomes sulphuretted hydrogen.* Phosphuretted hydrogen collected in a jar with a cap and stop cock, blazes when the jar is depressed into the water and the orifice opened; or if a bent tube be attached to the cap, and the bubbles be allowed to issue from beneath the water, they flash as they break into the air.†

OTHER VARIETIES OF PHOSPHURETTED HYDROGEN.

1. Sub-phosphuretted hydrogen gas.

(*a.*) *This is the gas, already named, which remains after the common phosphuretted hydrogen has deposited $\frac{1}{4}$ of its phosphorus*,‡ and has thus lost its spontaneous inflammability; it is called at present, sub-phosphuretted hydrogen, and by some proto-phosphuretted hydrogen.

(*b.*) *For perfect combustion it requires 1.25 volumes of oxygen;* .75 saturates the phosphorus, and .50 the hydrogen; as the vapor of phosphorus requires its own volume of oxygen, this gas is inferred to consist of 1 vol. of hydrogen, 0.0694 + 0.75 of a vol. of phosphorus, 0.6250 = .6944.

---

* We are not informed what becomes of the phosphorus; whether it is precipitated or remains suspended in vapor.

† It is supposed that many of these fires which are said to be seen at night, around burying grounds, and other places where animal and vegetable substances are undergoing decomposition, arise in part at least, from phosphuretted hydrogen. Travelling once, through a deep valley, in a dark night, between Wallingford and Durham, Conn. I was surrounded by multitudes of pale lambent lights; they were every moment changing their position, and some of them were within the reach of my whip; they were yellowish and not intense.

‡ Thomson.—Dumas says one third.

2. Hydro-phosphoric gas.—*Davy;* bi-hydroguret of phosphorus. —*Thomson.*

(*a.*) *Obtained by heating solid phosphorous acid away from air;* the hydrogen of the water of crystallization unites with a part of the phosphorus to form this gas, and the oxygen with another part to form phosphoric acid.

(*b.*) *A distinct gas, not spontaneously inflammable;* smell fetid, but less so than that of the phosphuretted hydrogen.

(*c.*) *At* 300° *Fahr. it detonates violently* with oxygen gas.

(*d.*) *Explodes in chlorine* with a white flame.

(*e.*) *Water absorbs* $\frac{1}{8}$ *of its volume.*

(*f.*) Sp. gr. .87*—more than twelve times as much as that of hydrogen gas.

(*g.*) *Potassium heated in it becomes a phosphuret,* and the volume of the gas is doubled.

(*h.*) Sulphur in the same manner produces sulphuretted hydrogen gas, equal to twice the original volume.

(*i.*) 3 volumes of this gas condense 5 of oxygen, 1 volume requires 2 of oxygen for its complete combustion, 1 for each of its constituent principles, forming phosphoric acid; and with 1½ vol. oxygen, phosphorous acid.

(*j.*) 1 volume of this gas absorbs 4 of chlorine.

Remarks.—Mr. Dalton says that there is only one variety of the phosphuretted hydrogen, that the others quoted are merely mixtures of this with common hydrogen, and that they may be separated by chloride of lime, which absorbs the former. He says that phosphuretted hydrogen requires 2 volumes of oxygen for saturation, and 8 volumes of water for its solution,† &c.

It is inconsistent with the design of this work to discuss the views of different writers on the subject of these compounds, particularly the elaborate researches of M. Dumas.‡ A full abstract of them is given by Dr. Ure, in his Dictionary, 2d Ed. p. 658, and the views of Prof. Rose are briefly stated by Dr. Turner, 2d Ed. of his Chemistry, p. 355. It is sufficient for the general student to know that there are either several varieties of phosphuretted hydrogen, or that the gas which has been so long known by that name, is mixed in different proportions with common hydrogen gas, which as already stated, is the opinion of Mr. Dalton.

---

* Davy.—.9658 Thomson. Theory would give it at .9721; twice the sp. gr. of hydrogen, = 0.1388,+ sp. gr. of phosphorus vapor, 8333.=.9721.—*Henry.* Mr. Dumas states it as 1.214.

† Thomson's Annals, Vol. XI, p. 7.

‡ Ann. de Chim. et de Phys. Vol. XXXI, p. 158.

PHOSPHURET OF SULPHUR, OR SULPHURET OF PHOSPHORUS.[*]

1. Preparation.

(*a.*) *It is unsafe to form this compound by melting the materials under water*, unless in very small quantities, say 60 or 80 grains, and with a heat not over 160° Fahr.

(*b.*) Mix the ingredients, the phosphorus in slices—the sulphur in flowers, and place them in a tube sealed at one end, and loosely corked; immerse this in water, and heat it gradually, till the combination is formed.[†] Or, melt phosphorus, not exceeding 30 or 40 grains, in a tube from ½ to ¾ of an inch wide, and 4 or 5 inches long; the sulphur may be thrown in, in successive small pieces. In all the modes, sulphuretted hydrogen is evolved.

2. Properties.

(*a.*) *Fusibility greatest when the proportions are equal*—or 1½ of sulphur to 2 phosphorus,[‡] congeals at 41; 1 of sulphur to 2 phosphorus, at 50°; with 1 to 4 at 60°; sulphur prevailing, it becomes less fusible; 1 of phosphorus to 2 sulphur congeals at 56°, 1 to 3 at 99°. Phosphorus 1, and sulphur 8, or even 30, give a solid and good compound for lighting matches, but they unite in every proportion.

(*b.*) *Decomposes water*, becomes acid, emits fetid gases, and if heated in contact with water to 210°, it explodes.

(*c.*) *Less inflammable when formed in the dry than in the humid way;* becomes very inflammable by kindling it by a hot wire in the tube, and suffering it to burn for a few minutes.

(*d.*) *Olive oil*, rubbed with this compound, and suffered to stand in the cold, *dissolves it, as do the essential oils.*

(*e.*) *When the solution is perfectly clear, it may be rubbed on the hands with safety*, and appears very luminous in the night.

(*f.*) *The solution in olive oil*, mixed in equal parts with oil of turpentine, *gives a beautiful shower of fire*, when poured out in the dark.

---

[*] For many interesting particulars, see Nich. Vol. VI, and VII; Accum and Briggs; Ann. de Chim. Vol. IV, p. 10; Quar. Jour. IV, p. 361.

[†] The young chemist should be very much on his guard in forming this dangerous compound; the mode in which I have succeeded the best, has been to prepare the materials as stated in the text, and then to hang the tube through a piece of board laid across a common tea-kettle, whose lid is removed; it contains cold water, and is placed over live coals contained in a table furnace, and left to itself; it ought not to be approached until the water has boiled and grown cold again. I have, when even all these precautions were taken, known several violent explosions, throwing the kettle to a distance.

Prof. Olmsted remarks, that if the phosphorus is dried by blotting paper, and the sulphur in a saucer, the danger of explosion is greatly diminished.

[‡] Thenard says 2 of phosphorus and 1 of sulplur.

PHOSPHURETS OF THE ALKALIES are scarcely formed, except the transient combination by which phosphuretted hydrogen is produced; they have but a momentary existence, and pass to the saline condition.

PHOSPHURET OF LIME.

1. PREPARATION.

(*a.*) A coated glass or earthen tube is partly filled with good lime, in pieces, occupying the middle; phosphorus is placed at one end, which is stopped with fire lute; the other end is closed with solid chalk; lay it across a furnace, and when the lime is red hot, draw the phosphorus into the heat, it sublimes, and the compound is formed; it must be kept close from the air.

2. PROPERTIES.

(*a.*) *Of an auburn brown color.*

(*b.*) *Thrown into water, emits phosphuretted hydrogen, which flashes in the air.*

(*c.*) Place some of it in a dish of water, and bring over it quickly a jar of common air, which produces a pretty fire work; we should be on our guard against explosion, which, especially if oxygen gas be used, is very liable to happen.

(*d.*) It is said,† that lime and phosphorus stratified in a long vial, buried in sand to the neck, and gradually heated, keeping just below redness till the combination is formed, will answer as a substitute for the tube experiment, and then the phosphuret may be kept in the same vial.‡

(*e.*) It is very possible that this substance is, at least in part, a phosphuret of calcium; but no accurate experiments have been made to determine this point.

(*f.*) If phosphorus be sublimed through carbonate of lime, the carbonic acid is decomposed, and charcoal deposited.

Remark.—From half an ounce of good phosphuret of lime, 60 cubic inches of phosphuretted hydrogen gas are obtained, by the agency of muriatic acid.

* * * * * * *

The phosphurets of baryta and strontia may be formed in the same manner, but they possess no properties that are peculiar, except that the phosphuret of baryta§ is employed for the formation of the hypo-phosphorous acid.

---

* If languid, warm water makes it succeed brilliantly, and sulphuric acid, (strong) added to the mixture, has the same effect. Muriatic acid has a similar effect, but not with so much energy.

† Aikins' Dict. Vol. II, p. 214.

‡ This has not succeeded well with me; the phosphorus is vaporized before the lime is sufficiently heated.

§ See Dr. Pearson's account of the phosphurets in the Phil. Trans.

SEC. V.—NITROGEN.

COMBINATIONS OF NITROGEN AND PRECEDING SIMPLE BODIES.

COMPOUNDS OF NITROGEN WITH OXYGEN, AND THE COMBINATIONS OF THESE WITH PRECEDING BODIES.

Remarks.—As it seemed difficult to advance at all without a knowledge of the composition of the atmosphere, the history of nitrogen was given in connexion with that subject. It now remains to detail the history of the other compounds into which nitrogen enters, in connexion with oxygen, and it seems to me that the properties of this very singular class of bodies will be best understood by taking them in the following order.

NITRIC ACID.—NITRIC OXIDE GAS, (*nitrous gas.*)—NITROUS ACIDS.—NITRATES OF ALKALIES.—NITROUS OXIDE, (*exhilirating gas.*)—NITRATES OF EARTHS.—NITRITES; *to be concluded by a recapitulation of the composition, &c. of the nitric compounds.*

NITRIC ACID.

1. HISTORY.—*First obtained by distilling a mixture of nitre and clay.* The discoverer was Raymond Lully, a chemist of the island of Majorca, born in 1235. Basil Valentine, in the fifteenth century, describes the process more minutely, and calls the acid *water of nitre;* subsequently it was called *spirits of nitre* and *aqua fortis;* the latter is still the name in the shops. *Called nitric acid* by the French chemists, in 1782; *because it is obtained from nitre.*[*] On the principles of the nomenclature, it would, at that time, have been called azotic acid, and the name azote was altered to nitrogen to make the terminology consistent.

2. PREPARATION.

(*a.*) For information merely, the original experiment of Mr. Cavendish may be repeated.[†] In that case, it was formed by *electrizing* for a great length of time, with many thousand shocks, *a mixture of oxygen and nitrogen gases,* in the proportion, by measure, of 5 parts of oxygen to 3 of common air, or 7 oxygen to 3 nitrogen, or common air by itself.[‡] It may be done, over quicksilver, in a glass tube,[§] furnished with gold or platinum wires; caustic potash, introduced before electrization, will absorb the acid as it is formed, and thus nitre will be produced, from which the acid may be extracted. Mingled in proper proportions, the gases nearly disappear, in consequence of their combination.

---

[*] Familiarly called saltpetre.

[†] See Phil. Trans. Vol. LXXV, 1785.

[‡] Oxygen and azotic gas were mixed by Mr. Cavendish, in the proportion of 416 of the former, to 914 of the latter, in bulk, in one experiment, and in another, in the proportion of 1920 : 4860, and (Phil. Trans. 1785,) he converted them totally into NITRIC ACID.

[§] A distinguished chemist, in London, informed me, in 1805, that he and a nobleman who was his pupil, had labored during a month to produce nitric acid by the original experiment of Mr. Cavendish, but without success. This goes only to prove that it is a difficult process, for the name of Mr. Cavendish is sufficient authority for any thing which he asserts.

(*b.*) *The usual process for nitric acid.**—A large retort, with an adopter, tubulated receiver† and sand heat; the lute, is clay, sand and flour, equal measures, mixed and kneaded together; proportions of the salt and acid, nitre 6, sulphuric acid 4 to 6; the nitre in fragments: if the receiver is not tubulated there should be an opening through it for gas to escape; heat slowly raised, receiver kept cool; there should be no water in it, if we would obtain a strong acid; the process lasts one hour, or two or more, according to the quantity; there is some red gas at the beginning, and much towards the end; the retort is clear in the middle of the experiment, and when the residuum puffs up, we stop the process. To extract the caput mortuum,‡ warm water is poured in very cautiously, and, at first, in very small portions, for there is great heat and ebullition; proceed carefully till the supersulphate of potassa is thus dissolved; if left in, it almost infallibly breaks the retort by crystallizing; the excess of acid may be driven away by heat, or neutralized by chalk, and then crystals of sulphate of potassa will be obtained.

(*c.*) *Nitric acid is freed from muriatic*, and in a good degree from the sulphuric, *by nitrate of silver*;§ *the sulphuric acid is* better *removed by distilling it again from* $\frac{1}{8}$ of the original quantity of very *pure nitre.*

(*d.*) *Nitrate of baryta also separates the sulphuric acid;* it must be re-distilled off from the precipitate, leaving $\frac{1}{8}$ or $\frac{1}{16}$ in the retort.

(*e.*) Pure nitre is prepared by dissolving and crystallizing nitre several times, the last time with the addition of nitrate of silver, to precipitate the muriatic acid. Such nitre will, if the salt does not soil the neck of the retort, and the heat is cautiously raised, and is not raised too high, give pure nitric acid in the first process.

(*f.*) *The colored acid may be made clear by long and cautious heating*, to expel the nitric oxide gas, and a receiver may be used to save any acid that rises. The acid is more easily cleared by a little black oxide of manganese, placed in the retort which imparts oxygen and converts the nitrous into nitric acid. Probably any other nitrate would answer to afford nitric acid, but the nitrate of potash is the best.‖

---

* Nitre may be decomposed by sulphuric acid in small quantities, with a naked glass retort, over a lamp or live coals, and the adopter is not indispensable, as the receiver is very little heated in the process.

† Furnished with a bent tube if you wish to collect the gases evolved.

‡ An old fanciful name given to the solid residuum from distillation.

§ Or nitrate of lead; but nitrate of silver is preferable.

‖ Dr. Thomson, (First Principles, Vol. I, p. 107,) says that pure nitre is *anhydrous*, and that if a little water be mechanically lodged between the plates of the crystals, it is easily dissipated by a moderate heat or by fusion. When such nitre in the proportion of $12\frac{3}{4}$ parts is decomposed by $6\frac{1}{8}$ parts of the strongest sulphuric

3. Properties.

(a.) *Its sp. gr. is usually* 1.5 *or* 1.55*; it has been obtained as high as* 1.62, *by Proust*;† supposed to be in its pure state an acid gas of sp. gr. 2440, air being 1000; this acid gas with water forms the common acid; that having the sp. gr. 1.55, contains nearly 86 per cent. of acid, and 14 water.

Table of the strength of nitric acid, from Thomson's First Principles, Vol. I, p. 114.

Equiv. of acid.	Equiv. of water.	Acid in 100.	Sp. Gr.
1	1	85.714	1.5500
1	2	75.000	1.4855
1	3	66.668	1.4546
1	4	60.000	1.4237
1	5	54.545	1.3928
1	6	50.000	1.3692
1	7	46.260	1.3456
1	8	42.857	1.3220
1	9	40.000	1.3032
1	10	37.500	1.2844
1	11	35.294	1.2656
1	12	32.574	1.2495
1	13	31.579	1.2334
1	14	30.000	1.2173
1	15	28.571	1.2012

(b.) *Hydro-nitric acid*, as it is called, *is a pale colorless fluid, like water*, with a pungent odor, and it emits smoke in the air.

(c.) It has all the acid properties in perfection.

(d.) *Highly corrosive, and turns the skin yellow.*

(e.) *Boils at* 248°, *and is distilled without change*; but this boiling point belongs to acid of the sp. gr. 1.42, containing acid .60 and water 40.

---

acid,* we obtain the strongest nitric acid, with sp. gr. 1.55. When the proportion of sulphuric acid is doubled, the retort is not so liable to be broken, but the nitric acid, obtaining a larger supply of water from the sulphuric acid, is of course weaker. When 12¼ parts sulphuric acid are mixed with 12¾ parts of pure anhydrous nitre, the whole of the nitric acid is obtained, but of the sp. gr. 1.4855, and its composition is 1 equivalent acid and 2 water. In the London Pharmacopeia, equal parts of nitre and sulphuric acid are ordered; this contributes to the formation of a bi-sulphate of potash, which is said to be necessary to the entire decomposition of the nitre, and affords two proportions of water, which are required to condense the whole of the nitric acid. The Edinburgh Pharmacopeia and the manufacturers use three fourths or four fifths of sulphuric acid, and these proportions are the best.

* It is well, before using it, to heat the sulphuric acid nearly to its boiling point, to expel the water it may have imbibed.

† Gay-Lussac says, (Ann. de Chim. et de Phys. Vol. I, p. 396,) that 1.510, at 18° centigrade, is the heaviest that had then, (1816,) been obtained.

Any acid, either weaker or stronger, boils at a lower temperature; if weaker, it is strengthened, if stronger, it is weakened by boiling; and acids of all degrees of strength come, by continued boiling to sp. gr. 1.42, which seems to be the strongest combination of acid and water. Acid of sp. gr. 1.369, contains half its weight of water; that of sp. gr. 1.30, has acid 40 and water 60, and boils at 236°.*

(*f.*) *Frozen at 2° below 0, Fah. if of sp. gr.* 1.3. When either stronger or weaker, it requires a much more intense cold, as much, in some cases, as to freeze mercury.†

(*g.*) *Exposure to light, colors it red, while oxygen gas is given out,* provided it be strong; and this happpens when it is weak, if it be previously mixed with sulphuric acid.

(*h.*) *Decomposed into oxygen and nitrogen gases, or nitric oxide gas, by being passed in vapor through a red hot earthen tube,* and the stronger the acid the more readily it is decomposed. A pendent candle just blown out, is promptly relighted by being plunged into the mixed oxygen and nitrogen; these may be analyzed by any of the eudiometrical methods, and their proportion ascertained. They will be found to be in nearly the reversed proportions of the atmosphere. Some nitric oxide gas usually comes over and produces red fumes of nitrous acid, which are soon absorbed by the water, and leave the oxygen and nitrogen mixed. *The decomposition of the solid nitrates by ignition affords similar results;* nitrate of ammonia, is however an exception, as will appear in its proper place.

(*i.*) *Causes ice and snow to melt, producing cold;* 4 parts strongest nitric acid with 7 of snow, sink the mercury from +32 to −30°, see tables of freezing mixtures.

(*j.*) *Attracts water from the air* and becomes weaker, but not in an equal degree with sulphuric acid.

(*k.*) *Acid 2, + water 1, at common temperature,* raise the therm. 112°, but if more water is added, this mixture lowers the temperature. Nitric acid, 58 measures, of sp. gr. 1.5, mixed with 42 of water, raises the temperature from 60° to 140°, Fahr. and on cooling, the 100 measures occupy 92.65.‡

(*l.*) *More or less affected and decomposed by all combustibles, and by most metals.*

(*m.*) *It explodes with hydrogen at a high degree of heat;* caution is required; it is best shown by passing the hydrogen gas from a flask, by means of a tube bent twice at right angles, through nitre melted in a crucible, when there is a slight explosion, and a flash at the passage of every bubble of gas; some caution is requisite.

---

* Dalton. Thomson. Henry.

† Cavendish, Phil. Trans. 1788.

‡ Ure, quoted by Turner.

(*n.*) *Boiled on sulphur, sulphuric acid is formed*, but without combustion.

(*o.*) *Poured on charcoal, there results a vivid inflammation;* it is best to pound ignited charcoal taken immediately from the fire; put it into a worthles glass vessel or a crucible, and add the acid gradually. Lamp black, or the charcoal of oils inflames more easily than common charcoal, but a mixture of the two more easily than either alone.

(*p.*) *Phosphorus is converted into phosphoric acid by the nitric;* if weak, it merely boils with red fumes of nitrous acid; *if very strong, and especially if warm, it burns with a splendid combustion;* it is thrown about in jets of fire and requires great caution; to render it the more beautiful, a tall narrow deep vessel should be used, but when the quantity of both substances is considerable, there is sometimes a dangerous explosion.*

(*q.*) *If phosphoric acid is desired, the common aqua fortis is strong enough;* it may be gently heated; the phosphorus is added in pieces, and when they are no longer dissolved, and readily take fire on coming to the surface, the process is through.

(*r.*) *Heat will expel any remaining nitric acid*, and if pushed far enough in a platinum vessel, we obtain glacial phosphoric acid.

(*s.*) *The easily oxidable metals*, iron, tin, zinc, copper, &c. *decompose the acid powerfully*, especially if hot.

(*t.*) *Very strong nitric acid*, poured from a glass fixed to a pole, *fires oil of turpentine, and other volatile oils*—the pole is for safety. A little sulphuric acid is mixed with the nitric, to concentrate it by removing a portion of water which it contains. The drying oils do not need the addition of sulphuric acid.

4. COMPOSITION AND COMBINING WEIGHT.—When we have finished the history of the compounds of nitrogen and oxygen, we will review that of nitric acid, which cannot perhaps be fully understood without an acquaintance with all the acids and oxides, which have nitrogen for their basis. We may state at present, that the proportions of the elements of nitric acid, by weight, are,

74.13	oxygen, - -	286	by volume, nearly	250
25.87	nitrogen, -	100	" "	100
100.00		386		

---

* This circumstance has happened so often in my own experience, with nitric acid distilled from very pure nitre, with two thirds its weight of sulphuric acid, and without any water in the receiver, that I cannot but repeat the caution that the operator should be much on his guard. With a stick of phosphorus as long as a finger dropped into 2 or 3 oz. of strong nitrous acid, I have known explosions like those of a swivel, and the fragments of glass have wounded persons at a considerable distance. See Am. Jour. for Dr. Hare's experience.

and its constitution, 5 equivalents of oxygen =40, *and* 1 *of nitrogen* =14, *its own equivalent being therefore* 54.*

Liquid nitric acid, sp. gr. 1.50, contains 2 proportions of water, 18+54=72 for the representative number.

Dr. Thomson assigns the sp. gr. 3.75, to the dry gaseous acid, and this number is produced by multiplying .06944, the specific weight of hydrogen, by 54, that of nitric acid.

5. Polarity.—In the galvanic circuit, this acid is *attracted to the positive pole*, and is therefore electro-negative.

6. Uses.

(*a.*) *The nitric acid is a very important agent in chemistry.* From its yielding its oxygen with so much facility, it is often employed to oxidate substances of various kinds, and particularly several of the acids are formed in this way. *It attacks and decomposes all vegetable and animal substances*, giving oxygen to their carbon, to form carbonic acid, and to their hydrogen to form water.

(*b.*) *It is also much used in the arts;* by engravers in etching their copper plates; in the solution of metals, and in dyeing; especially with muriatic acid, to prepare tin as a mordant for cochineal, to produce the scarlet; and in forming and fixing other fine colors. *It is employed in medicine*, particularly in liver diseases; as an auxiliary in some other cases, both internally and externally, but in the latter case, diluted, so as merely to prick the skin; as a very valuable remedy in fevers—typhus, petechial and malignant; and as a tonic. It is diluted to such a degree, as to be only agreeably acid, and it may be qualified by sugar and aromatics.

The diluted nitrous acid of the Edinburgh and Dublin pharmacopeias, is composed of equal weights of nitrous acid and water.

(*c.*) *Vapor of nitric acid expelled from nitrate of potassa by sulphuric acid, is used in fumigations to counteract febrile effluvia;* it appears to possess a good deal of efficacy in that way, and is not inconvenient to the patient, to whose bed side it may be carried without harm; *no heat should however be applied*, as it will then emit very suffocating vapors of nitrous acid. *Half an ounce of nitre is mixed with 2 drachms of sulphuric acid*, and the vapor from this will fill ten cubic feet. For this application, Dr. Carmichael Smith received from the British Parliament, a reward of 5000 pounds sterling.

(*d.*) *It is one of the great acids of commerce.* It forms nitrates with the salifiable bases. All its salts are soluble; it is separated from them all in a state of decomposition, by heat, and the bases, ammonia excepted, are left behind.

---

* Henry, Vol. I, p. 324; Thomson's First Prin. Vol. I, p. 112; Ann. of Philos. N.S. VIII, 299.

7. **Miscellaneous**—In the arts, copperas calcined to redness, is mixed in equal quantities with dried and purified nitre; the distillation is performed in an earthen retort or an iron pot with an earthen head, and a very strong fuming acid is thus obtained, called aqua fortis. If the materials have not been before heated, they will afford water and a diluted acid which fumes very little; it is called single aqua fortis. The sulphate of potassa is separated by solution, and the oxide of iron is sold for polishing metals; it is called colcothar. On the continent of Europe, they use clays, boles and other earths containing silex; the affinity exerted by these earths, towards the alkali of the nitre decomposes the latter at a red heat. As crude nitre is employed, the acid which is called spirit of nitre, is contaminated with muriatic acid.

The French distil the nitric acid in large cast iron cylinders, but when iron is used, more of the nitric acid is decomposed, and there is of course more nitrous acid produced.

The corrosive fumes of nitrous acid are carefully avoided in the manufactories; they sometimes cause the workmen to spit blood. The double aqua fortis is half as strong as pure nitric acid; and single aqua fortis being half as strong as double, is of course one fourth the strength of the strongest acid. Nitric acid is distinguished by its ready action on copper and mercury; by forming nitre with potash, and nitro-muriatic acid with muriatic acid, and thus becoming capable of dissolving gold,* by bleaching a very dilute solution of indigo, if in the proportion of $\frac{1}{400}$, or turning it yellow if $\frac{1}{500}$, when a few drops of sulphuric acid are added; also by the scintillation which it produces when dropped upon ignited charcoal. For economical purposes, 100 good nitre, 60 strong sulphuric acid, and 20 of water, form a good proportion.

Dr. Ure states, as the result of his own experiments, that if the respective terms of dilution of nitric acid with water, be taken as an arithmetical, the densities will be in a geometrical series.†

In its concentrated state, it is a deadly poison, corroding and destroying the animal organs.

NITRIC OXIDE GAS—NITROUS GAS—OR DEUTOXIDE OF NITROGEN.

1. **Remarks.**—*In* the *strictness* of logical arrangement, *this oxide should be described after the protoxide* or exhilirating gas, *and both of them before nitric acid*, but as it is obtained by the decomposition of the latter, its history will probably be most intelligible if introduced here.

---

* But muriatic acid produces a similar fluid with the chlorates and bromates.

† Dict. 2d Ed. p. 57.

2. HISTORY AND NAME.—It appears from *Dr. Hale's* vegetable statics, that he *obtained this gas more than a century ago*, but Dr. Priestley first examined its properties with attention in 1772.* He called it *nitrous air;* it is called also *nitrous gas*, and *nitric oxide gas*, and *deutoxide of nitrogen*. The two last names being the most proper will be employed, and for brevity the term nitric oxide will be commonly used.

3. PREPARATION.

(*a.*) It is best obtained *by the action of nitric acid upon mercury or copper:* for both economy and purity the latter is preferred.

(*b.*) *Nitric acid, sp. gr.* 1.2 *or* 1.3, *is poured upon cuttings of copper.* With shears like those used by the tinmen, cut sheet copper into pieces of such size that they will easily slide into a glass retort; add common aqua fortis, or any of the varieties of nitric acid of the shops, till the copper is more than covered; then add hot water, by little and little, till the action comes on; let the first red vapors escape, and when the neck of the retort is nearly clear of the red color the gas may be saved.†

(*c.*) If any of *the copper clippings* are left, they *may* be rinsed with water and allowed to *remain in the retort for another operation.*

(*d.*) If a diluted acid be used, the heat of a lamp or of a few coals may be employed. *In general, the gas comes rather suddenly; continues to flow rapidly for a few minutes and then remits;* it is of little use to urge it with heat beyond this point; some gas may indeed be obtained, but it appears to be principally that which was dissolved in the nitric acid, and, although there may be an active ebullition, little is disengaged besides aqueous vapor.

(*e.*) *An economical process* for obtaining nitric oxide gas is, to *mix sulphuric acid and nitre in the proportions to afford nitric acid*, and then to add to the mixture some pieces of copper.‡

(*f.*) THEORY of the process.—*The nitric acid imparts oxygen to the copper* and converts it into peroxide, which unites with a portion of acid that has not been decomposed and forms nitrate of copper; the nitric oxide contains all the nitrogen of the acid decomposed and as much of the oxygen as remains after the oxidation of the copper.

---

* Priestley on Air.

† *The contrast presented by the green* solution of the copper *and the red* vapor of nitrous acid *is very striking;* the solution, which will be nitrate of copper, (usually with excess of acid,) should be saved for future uses.

‡ In some of the processes for nitric oxide, a portion of nitrous oxide, and even of nitrogen, is evolved.

(*g.*) *Specific gravity;* air being 1. *it is* 1.041, *and* 100 *cubic inches* at 60° Fahr. and 30 inches of the barometer *weigh* 31.770* grains; compared with hydrogen its weight is 15.

4. Composition.

(*a.*) *Potassium,* heated in this gas, *abstracts* 50 *per cent. of oxygen and leaves the same quantity of nitrogen;* as 50 cubic inches of oxygen weigh 16.944 grains, and 50 of nitrogen 14.826, its weight is plainly, for 100 cubic inches, 31.770, as stated above. As there is no condensation attending the union of the gases which unite in equal volumes, we easily obtain the specific gravity by calculation; thus the specific gravity of oxygen gas, air being 1, is - 1.1111
that of nitrogen gas is .9722 - - - - - .9722

The sum of which 2.0833 divided by 2=1.041.

By volume, therefore, *this gas consists of* 50 *oxygen and* 50 *nitrogen; by weight of* 53.4 *oxygen and* 46.6 *nitrogen;* the difference between the number expressing the weight and the volume is owing to the difference in the specific gravity of the two gases.

(*b.*) *Heat,* applied in porcelain tubes, *and electric sparks decompose this gas;* the product resembles common air, and a portion of the original gas is left undecomposed.

(*c.*) Iron, zinc, tin, arsenic, phosphorus, charcoal and the alkaline sulphurets, by abstracting oxygen, convert it either into nitrous oxide or nitrogen.

5. Constitution.—*The equivalent number* of this gas *is obtained by adding* 14, which is the number for nitrogen, *to* 16, which represents two equivalents of oxygen, *and* 30 *therefore represents the nitric oxide.*

6. Properties.

(*a.*) *Invisible, colorless, and permanently elastic.*

(*b.*) *Not much absorbed by water,* unless previously boiled, when it takes up, by agitation, about $\frac{1}{11}$ of its bulk, which is again expelled by ebullition.† Dr. Turner states the absorption at $\frac{1}{9}$ or about 11 per cent.‡

(*c.*) *Very hostile to life; warm blooded animals, immersed in it, are killed almost instantly, and it destroys the irritability of the heart. It kills by suffocation and by excoriation.* It becomes nitrous acid by meeting with the oxygen in the air, in the cavities, and excites the glottis to violent spasmodic action with most distressing irritation.[*]

---

* Its weight was formerly stated by Sir H. Davy at 34.26 grains.

† The impregnated water is said to generate nitrate of ammonia after long keeping; this is perhaps not extraordinary, as all the elements are present, namely, hydrogen and oxygen in water, and oxygen and nitrogen in the nitric oxide.

‡ Elements, p. 186.

(*d.*) *Action on combustibles.—This is very various; some combustibles that burn in common air, do not burn in this gas*, as a candle, sulphur, and most common combustibles, which, although on fire, are extinguished by immersion in nitric oxide.

Phosphorus, if previously kindled, burns with great energy, but it may be melted in this gas without inflaming. Homberg's pyrophous is spontaneously inflamed.

Charcoal, previously ignited, takes fire, but *burns feebly*.[†] *Hydrogen gas, mingled with the nitric oxide, does not explode by a lighted candle, but burns quietly*, with a greenish white flame, of peculiar and agreeable hue, which is modified between that of the yellow vapors of nitrous acid, and the pale bluish flame of the hydrogen.

Carburetted hydrogen—no explosion, except between 7 measures of nitric oxide gas, and 1 of the olefiant.

Spongy platinum acts upon a mixture of hydrogen gas with nitric oxide, in proper proportions; acid and nitrogen and watery vapor are evolved.

Ammonia 100 *parts, and this gas* 150, *detonate by the electric spark*, and by a spontaneous action, nitrogen is liberated in the course of a month.[‡]

(*e.*) *Action on oxygen gas.—This is the most interesting of all the relations of nitric oxide gas.* Wherever it meets with oxygen gas, either alone, or in mixture with other gases, it produces deep brownish red fumes of nitrous acid.

This property need be indicated here, only in a general way, because it will be more fully stated under the nitrous acid.

1. Fill a tall glass tube with infusion of litmus, or purple cabbage; pass up some bubbles of nitric oxide gas, that have stood for an hour or two over water; there will be no alteration in the color of the litmus; now add some oxygen gas, or common air; there will still be no change till the bubbles reach the nitric oxide; then red fumes will be produced, which will promptly change the color of the liquid to red, and the water will rise rapidly, on account of the absorption of the acid vapor.

2. The above experiment may be repeated, only using a tall air jar, and common air. The observer who sees the result for the first

---

[*] As I once experienced, having breathed some of it, for nitrous oxide, from an air vessel. Insects that will live in some of the other noxious gases die in this, and fishes die in water impregnated with it.—*Murray.*

[†] Murray. Most authors say brilliantly, but in numerous trials, I could never make it burn at all. It will never answer for a class experiment. May it not be that nitric oxide gas has been in this case confounded with nitrous acid vapor, which is more energetic in supporting combustion?

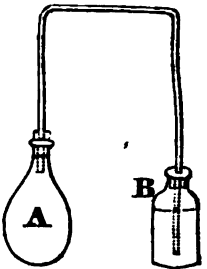
[‡] Henry.

time, is astonished at the deep blood red color of the fumes, and the rapid absorption, especially when oxygen gas is employed. In this case, the hand laid upon the jar, in which the combination is going on, is sensible of considerable heat.

3. Lift out of the pneumatic cistern, a large air jar, filled with nitric oxide gas, having previously slipped under it a pane of window glass; reverse its position, and suddenly remove the glass plate; immediately a dense cloud of red nitrous acid vapor will rise from the mouth of the jar, and the hand placed in the current, will be warmed. The acid will soon disappear, being absorbed by the watery vapor in the atmosphere.

NITROUS ACIDS.

1. *General Explanation.*—It is obvious, from the statements that have been made, that whenever nitric oxide gas is mingled with free oxygen gas, nitrous acid is produced, and thus these gases become very delicate tests of the presence of each other. It is also true, that nitric oxide willl sometimes detach oxygen gas from combination, and form with it nitrous acid.



(*a.*) Prepare a flask with a tube bent twice at right angles, thus: in the flask A, place the copper and diluted nitric acid: in the bottle B, some pale colorless nitric acid. As soon as the nitric oxide gas begins to be evolved, the pale acid will change its color, and pass rapidly through many shades of yellow, ending with deep green, while blood red fumes will rise from the surface. These changes are owing to the absorption of the nitric oxide gas, by the nitric acid; this is at the same time partially decomposed, giving oxygen to the nitric oxide gas, which is thus converted into nitrous acid, and in this state mingles with the still undecomposed nitric acid, and thus presents a variety of shades of color;* "even a little more than 1 per cent. being sufficient to impart a pale yellow color."

(*b.*) *In the process for nitric acid* from the nitrate of potash and sulphuric acid, as already described, p. 447 it is now obvious that the *red fumes* which appear slightly at the *beginning*, and abundantly at the *end of the distillation, are owing to the decomposition* of a portion of *nitric acid*, giving both nitric oxide, and oxygen gas, which again unite in different proportions from the original ones, *and thus produce fuming nitrous acid.*

---

* Heat, gradually and long applied, will discharge this color, and dilution with water does it instantly, while red fumes are emitted.

In the middle of the process, when the first effects of the sulphuric acid are over, and the materials have not as yet become very hot, the nitric acid passes, without decomposition, and by changing the receiver, we obtain it nearly colorless. If any combustible is mixed with the materials, the red fumes are much increased, as the acid is then decomposed more rapidly than before.

(c.) *In all cases where nitric acid acts on combustibles, or on metals, it becomes colored, and emits red fumes, especially if in contact with the atmosphere;* this is owing to the generation of nitrous acid, in consequence of the extrication of nitric oxide gas, and its subsequent reoxigenation to produce nitrous acid.

(d.) It follows, that *nearly all the acids of the nitric family, found in the shops, and in the arts, and all that are colored, are mixtures of nitric and nitrous acids;* but the nitric acid usually prevails, and such acids by uniting with bases, form true nitrates; still it is true that the purest and strongest nitric acid, and the purest and strongest nitrous acid are scarcely known, except in the hands of the philosophical chemist; the pale acid of the shops is usually a nitric acid, diluted, more or less, with water; and all the colored acids, may, by additional dilution, or by the proper application of heat, be brought to the condition of nitric acid.

(e.) *Still,* although there are many varieties in the weight, color, fuming properties, and energy of the nitrous acids of the arts, *we must not suppose that there is a great diversity of real nitrous acids, and that the nitric oxide and oxygen "can unite in every proportion"* within certain limits. "The true explanation is, that *the mixture of these gases may give rise to three compounds, the hyponitrous, the nitrous, and the nitric acids,* and that if certain precautions are adopted, either of them may be formed, almost if not entirely, to the exclusion of the others."*

HYPO-NITROUS ACID.

1. Name and History.—Called by some *per-nitrous,* but *hypo- or sub-nitrous seems the most proper name,* since it is less energetic as an acid than the nitrous and nitric, and also contains less oxygen. First obtained by Mr. Dalton,† and Gay-Lussac.‡

2. Process.

(a.) *Mingle over mercury, in a glass tube, containing a strong solution of pure potassa,* 400 *measures of nitric oxide gas, with* 100 *of oxygen.* The compound thus formed, will be absorbed by the alkali, and is supposed to be the hypo-nitrous acid.

(b.) If 100 measures of nitric oxide gas be exposed for three months to a solution of pure potassa, over mercury, 25 measures of nitrous oxide (protoxide) will be left, the remainder having combined with the alkali in the form of hypo-nitrous acid, oxygen having been afforded by one portion of the nitric oxide, which was thus reduced to nitrous oxide, while the other, by the aid of the oxygen, became nitrous acid.

---

* Turner.

† Thomson's Ann. Vol. X.

‡ Ann. de Chim. et de Phys. Vol. I, p. 400.

(*c.*) Gay-Lussac supposes that he obtained the same acid by distilling the nitrate of lead, the volatile product being condensed in a receiver, kept cold by a freezing mixture.* But it is perhaps, not certain that the hypo-nitrous acid has yet been obtained in a state of freedom.

3. PROPERTIES.

(*a.*) *The acid* obtained by Gay-Lussac, from the destructive distillation of nitrate of lead, *boiled at* 79° *Fahr. and was dissipated in very dense red fumes.*

(*b.*) *Poured into water, nitric oxide gas was abundantly liberated,* "and the water became blue, green, and yellow, according to the proportion added."

(*c.*) *Sulphuric acid,* either strong, or a little weakened, and at a moderate temperature, *forms with the hypo-nitrous acid, four sided prisms,* which, as well as the fluid in which they are produced, emit nitric oxide gas by the contact of water.

(*d.*) *Nitrous acid vapor, passed into sulphuric acid gives also a similar compound.*†

4. CONSTITUTION.—*Hypo-nitrons acid appears to consist, by measure, of* 200 *of nitrogen to* 300 *of oxygen, or of* 100 *to* 150; for since 100 measures of oxygen (see 2,) are mingled with 400 of nitric oxide to produce hypo-nitrous acid, and as nitric oxide consists of equal volumes of nitrogen and oxygen, it follows that the proportions are as above stated. Also, in the experiment 2. (*b.*) "deducting from the nitrogen and oxygen originally contained in the nitric oxide gas, the quantities constituting 25 of nitrous oxide, we shall find that 25 volumes of nitrogen, and 37.5 of oxygen had disappeared and formed a new compound, which was absorbed by the potassa.

Thus—100 nitric oxide gas	=50 nitrogen	+50	oxygen,
25 nitrous oxide gas	=25 "	+12.5	"
	25	37.5	

and 25 : 37.5 : 100 : 150."—H.

These are exactly the proportions assigned by Gay-Lussac to the hypo-nitrous acid.

---

* Dulong and Dr. Thomson, however, suppose that the acid obtained in this case was the real nitrous.—*Murray.*

† Also by mingling oxygen gas, sulphurous acid, nitric oxide gas, and aqueous vapor, a similar compound is produced. Clement and Desormes, its discoverers, supposed it to consist of sulphuric acid and nitric oxide gas.—H.

The representative number of hypo-nitrous acid is 38, made up of 1 proportion of nitrogen, 14, and 3 of oxygen, 24; thus answering to 1 volume of nitrogen, and 1½ of oxygen—1 volume of oxygen representing two proportions, viz. 16.

5. *The hypo-nitrous acid cannot be obtained* from its alkaline combinations *in the isolated form,* for whenever a stronger acid is added, to separate it from the alkali, it is decomposed into nitrous acid, and nitric oxide gas.

NITROUS ACID.

It has been already explained, in what sense this term has been generally used by chemists. It now appears that there is a distinct and peculiar acid, to which the term may be properly applied.

1. PREPARATION.

(*a.*) According to Dr. Thomson*—*the distillation of dry nitrate of lead into a receiver kept cold by a mixture of snow and salt, affords this acid in purity;* Gay-Lussac considers it as the hypo-nitrous.†

(*b.*) Sir Humphry Davy obtained it *by mixing in a vessel* deprived of air, 2 *volumes of nitric oxide and* 1 *of oxygen,* the gases being both dry. The condensation, according to Davy, is into one half; according to Gay-Lussac and Dr. Thomson, into one third of their original volume.

(*c.*) The correct performance of this experiment requires a glass globe adapted to the air pump, and also to glass jars from which the two gases can be introduced in their proper proportions.

(*d.*) *The common class experiment of mingling the gases by pouring them into glass jars through water,* in the pneumatic cistern, *gives a mixed acid;* composed probably of the three varieties—nitric, nitrous, and hypo-nitrous.

2. PROPERTIES.

(*a.*) *In dry glass vessels, it forms a deep blood red vapor, or* perhaps it might be called a *gas.*

(*b.*) *It is,* however, *condensed into a liquid by a low temperature.* The density of the anhydrous acid is 1.451.

(*c.*) We have the authority of Dulong and of Dr. Thomson, that the red fuming acid distilled into a cold receiver from nitrate of lead, is really anhydrous nitrous acid.

(*d.*) It‡ is *very corrosive—intensely acid—odor very pungent,—color, yellowish orange*—at common temperatures, it is a fuming liquid, but evaporates rapidly and boils at 82°§ Fahr. The exhalations are the common nitrous acid vapors, which, when once mingled with other gases, require a very intense cold to condense them.

---

[*] Elements, Vol. I, p. 120.

[†] Ann. de Chim. et de Phys. Vol. I, p. 405.

[‡] It will be observed that this description applies also to what Gay-Lussac considered as hypo-nitrous acid; see his memoir, Ann. de Chim. et de Phys. T. I, p. 405.

[§] Berzelius remarks that nitrous acid of the same density with nitric that boils at 236°, boils at 160°.

(*e.*) *Action of water. To form liquid nitrous acid, nothing more is necessary than to add this vapor to water*—mixed *with a large quantity* of this fluid, *it becomes nitric acid*, which remains colorless in the water, while a quantity of nitric oxide gas escapes into the air, producing the usual red fumes.

But if the nitrous acid is *added to a very little water, the gas is retained and the fluid becomes green;* with an intermediate quantity of water, the anhydrous nitrous acid, when dropped in, emits at first, a considerable quantity of red fumes, which however diminish as more acid is added, and finally cease.

In the progress of the addition of the acid to the water, (as has been already stated under the hypo-nitrous acid,) the liquid passes through shades of greenish blue, and green of various tints, and becomes at length, orange yellow, which is the color of the acid itself. These changes of color are evidently owing to a mixture of different proportions of the three acids, and of the nitric oxide.*

(*f.*) *Action on animals; highly irritating and suffocating in the glottis;* it should be avoided as much as possible. In the numerous experiments of the laboratory, in which nitrous vapors are disengaged, it sometimes produces permanent injury, and often a distressing stricture of the chest, with a continued sense of pressure and suffocation.

(*g.*) *Action on combustibles. A candle burns in this vapor with some brilliancy, and phosphorus burns with splendor*—ignited charcoal continues to burn, but with a dull red light.

(*h.*) *By calculation from the weight of the elements and their condensation, this acid,* in the aërial form, *must weigh* 65.3 *grains,* at a medium temperature and pressure.

(*i.*) *Action on colors.*—It is scarcely necessary to add that this acid *reddens litmus and* affects *the other test colors,* as the acids generally do.

(*j.*) *The nitrous acid cannot be combined directly with the bases;* it affords with potassa, for instance, nitrate and hypo-nitrite, without any proper nitrite.†

3. *Test for nitrous acid.*—We owe to Gay-Lussac the knowledge of the fact that *the red sulphate of manganese becomes instantly colorless by the action of the nitrous acids;* which, by detaching oxygen, bring it to the state of white sulphate, while nitric acid has no such effect.

4. Representative number and constitution.—As nitrous acid is formed from 2 volumes of nitric oxide, consisting of equal volumes of oxygen and nitrogen, with the addition of one volume of

---

* For an ingenious theoretical explanation, more in detail, see Turner's Elements, 2d Ed. p. 225.

† Ann. de Chim. et de Phys. T. I, p. 410.

oxygen, it consists obviously of 4 *equivalents of oxygen* 32, *and* 1 *of nitrogen* 14, *which make the number representing it*, 46.

5. USES.—*Most of the acids of this class used in chemistry and the arts, and even in medicine, are, as already stated, rather nitrous than nitric acids, or rather mixtures of the two or even three varieties.*[*]

In medicine, this fact is of no moment, because the acid is always given largely diluted with water, and in this state, it is a weak nitric acid; and indeed, in most of the arts, it is used in a state of dilution. For the purposes of oxidation and combustion, the nitrous acids are used indiscriminately with the nitric; and the highly fuming acids, if equally concentrated, are thought to be even better for some brilliant experiments, such as the combustion of oils, of charcoal and of phosphorus. In chemical analysis, the nitric acid is generally employed; the nitrous is resorted to only occasionally.

APPENDIX TO THE HISTORY OF THE NITROUS ACIDS.

1. *Application of nitric oxide gas.*—It is obvious, from the preceding statements, that nitric oxide gas and oxygen gas, are mutually tests. To know whether there is in any gas a mixture of free oxygen or of common air, it is necessary only to add a little nitric oxide, when, if there is any uncombined oxygen gas present, the red fumes will appear. So far as this fact goes, the nitric oxide is an important agent in the hands of the chemist, but, as regards the amount of oxygen present, there has been much diversity in the results obtained in different modes of operating. As the causes of this diversity could not be fully understood until we had become acquainted with the nitrous acids, this subject has been reserved for the present place.

2. *Common air. When*, in a glass receiver *over water, nitric oxide gas is mixed with common air*, the red fumes appear, and by mingling them in proper proportions and in a proper manner, *the whole of the oxygen will be withdrawn, and the nitrogen will be left*—the nitrous acid being absorbed by the water.

3. *Oxygen gas.*—In the same manner, *oxygen gas will be absorbed only with more energy*, and it can be known in either case, which gas is in excess, by adding cautiously and in small quantities, either oxygen gas or nitric oxide; *if there is a residuum of either gas, there will be red fumes, on adding the other.* If pure oxygen gas is employed, and pure nitric oxide, in proper proportions over water, the absorption will be entire, and either gas, by adding the other, can be completely withdrawn from any mixture of gases.

---

[*] They are generally, described as nitric acid, holding in solution variable quantities of nitric oxide gas; but the more correct view appears to be that in the text (and on p. 457 *d.*) I have always found that the fumes obtained by heating or diluting the colored and fuming acids, are still more red and fuming, and indeed, it seems impossible that nitric oxide gas, should be in contact with nitric acid, without decomposing it, and taking enough of its oxygen, both to form and to leave nitrous acid, and the same effect will of course be produced by any combustible body.

4. *Apparent caprice.*

(*a.*) It has been found, however, that *the amount of oxygen absorbed, is very different in different cases*, and that it is influenced by the proportion in which the gases are mixed—the time that elapses after they are mixed—the size and form of the vessels—the greater or smaller surface of the water over which, and the rapidity with which, the mixture is made; and perhaps by other causes, such as agitation, temperature and order of mixture.

(*b.*) According to Davy, when large quantities of nitric oxide gas are added to small quantities of oxygen in vessels of large diameter, the absorption is from 2 to 3 of nitric oxide for 1 of oxygen—but if large quantities of oxygen are added to small quantities of nitric oxide gas in narrow tubes, the absorption is from 1 to 1.5 of oxygen in volume, and 2 of the nitric oxide gas.

(*c.*) *Surface of water.*—In general, *the larger the surface of the water, the more rapid the absorption*—and therefore for want of time, less oxygen is combined; in such case, more of the nitrous and less of the nitric acid will be formed.

(*d.*) *Cause of the variable absorption.*—Dr. Priestley, supposing that the nitric oxide and oxygen combined in only one proportion, very early employed them in eudiometry—but he was ignorant of the fact that they combine in three proportions; producing hypo-nitrous, nitrous and nitric acids, and that it is the varying production of one or another of these, and in different proportions, that creates the apparent caprice.

(*e.*) *Can the uncertainty be removed?*—Dr. Henry, in his Elements—Mr. Dalton, in the 10th Vol. of the Annals of Philosophy, and Gay-Lussac, in the 2d Vol. p. 247, of the Memoires d'Arceuil, have given minute directions how this may be with more or less certainty effected.

(*f.*) *The process of Gay-Lussac*, resembling the original one of Dr. Priestley, is worthy of being mentioned.

In a wide jar, a common tumbler glass, or a tube not less than 1½ inch in diameter,* add 100 measures of nitric oxide, to 100 of common air; the absorption will be complete in half a minute or a minute; the residue being measured in a graduated tube, will indicate a diminution of 84 measures out of the 200; one fourth† of the diminution is oxygen, =21, and 84 − 21 = 63, the proportion of nitric oxide gas that has been acidified.

In applying this process to mixed gases, containing sometimes more and sometimes less than the oxygen in the air, the result was found to be correct. When the proportion of oxygen was greater than in the air, the quantity of nitric oxide should of course be increased, that it may be present in excess.

---

* Murray.

† The division by four seems to be founded on experience only, as no reason appears why that number should give in this case a uniform result.

(*g*.) *The process of Davy.*—Nitric oxide gas being largely and readily absorbable by the green sulphate, and the green muriate (proto,) of iron, in that condition will attract powerfully the oxygen of the air.

The nitric oxide which is to be used, should be previously agitated in a tube, with one of these solutions, in order to determine whether there is nitrogen mixed with it. A strong watery solution of one of the salts just named, the acid being also saturated with the oxide of iron, is next to be fully impregnated with the nitric oxide; it should be kept in small divided portions in close vials, and applied as it is wanted, in Dr. Hope's Eudiometer, or in some other adequate instrument.

The protosulphate of iron is preferred, but the solution is liable to spontaneous decomposition, the protoxide of iron attracting oxygen, both from the water and the nitric oxide, and the nitrogen of the latter, combining with the hydrogen of the former, ammonia is generated. Gas is said also to be emitted.—See Davy's researches.

Dr. Hare remarks, "as nitric oxide consists of a volume of nitrogen and a volume of oxygen uncondensed, to convert it into nitrous acid which consists of a volume of nitrogen, and two volumes of oxygen, would require one volume of oxygen. Of course, if nitrous acid be the product, one third of the deficit produced, would be the quantity of atomspheric oxygen present. This would be too much to correspond with the formula of Gay-Lussac."

"Supposing hyponitrous acid produced, only half as much oxygen would be required, as is necessary to produce nitrous acid; so that instead of the two volumes of nitric oxide taking one volume, they would take only a half volume. The ratio of ½ in 2.½, is the same as 1 in 5, or one fifth, which is too little for Gay-Lussac's rule."

"The formula recommended by Dr. Thomson, agreeably to which, ⅓ of the deficit is to be ascribed to oxygen gas, is perfectly consistent with the theory of volumes, and much more consonant with the results of my experiments, than that recommended by the celebrated author of that admirable theory."*

---

* "The late Professor Dana ingeniously reconciled Gay-Lussac's statement, with the theory of volumes, by suggesting that a half volume of oxygen may take one volume of the nitric oxide, and another half volume of oxygen, two volumes.

Vol. Vol.
½ oxygen takes 1 oxide and forms nitrous acid.
½ oxygen 2 oxide and forms hyponitrous acid.
— —
Deficit due to oxygen is as 1 to 3

This result is evidently dependent upon the contingencies, which may prevent nitrous acid from being the predominant product."

Antiseptic properties of nitric oxide.—Nitric oxide is thought to be an antiseptic. Dr. Priestly says that it renders bladders in which it has been kept imputresible.

He tried many experiments on the preservation of meats by this gas. It generally saved them from putrefaction, and even stopped the progress of putrefaction already begun, but meats preserved in it had always a bad taste.

NITRATES OF ALKALIES.

A highly important and interesting class of salts; the principal nitrate, that of potash, having been known from remote antiquity.

GENERAL CHARACTERS.

1. Soluble, and crystallizable by the cooling of the hot solution.
2. At a red heat, detonating with combustibles.
3. Decomposed by sulphuric acid, nitric or nitrous acid being evolved.
4. Producing chlorine and dissolving gold leaf, when decomposed by muriatic acid.
5. Totally decomposed by heat, and (nitrate of ammonia excepted,) affording oxygen, mixed more or less with other gases.

NITRATE OF POTASSA.

1. SYNONYMES.

Nitre—salt petre.—The nitre of the scriptures is carbonate of soda.[*]

2. HISTORY.—*Known to the Romans; to the Chinese, from remote antiquity, and to the earliest chemists.*

(*b.*) Roger Bacon, in the thirteenth century, mentions it under the name of nitre. Although the subject of experiments for many centuries, Hooke and Mayhow, in the 17th century, having come very near discovering its real character, and Hales, in the beginning of the 18th, having extracted from it by heat, a great quantity of gas, its nature was not understood till the era of the modern chemistry.

3. PREPARATION.—*By saturating pure nitric acid with potassa, or its carbonate,* and then evaporating and crystallizing. But it is not necessary to prepare it, as it is found abundantly in commerce, and sufficiently pure for most purposes in chemistry.

4. PHYSICAL PROPERTIES.

(*a.*) The most common *form of the crystals is that of the six sided prism,* with a wedge-shaped termination.

---

[*] The word *nitre* is mentioned only twice in the sacred writings, viz. Prov. xxv, 20. and Jeremiah, ii, 22. It has been already mentioned (p. 251, Soda,) that in the first intsance, allusion is made to an effervescence produced by an acid, and in the second to a detergent, or cleansing property; neither of which belong to nitrate of potash, but both of them to the carbonate of soda—the natron of the Greeks—the nitrum of the Latins. With this understanding, the allusions are appropriate and beautiful; otherwise unmeaning; and this use is sustained by Pliny, and other ancient authors. The carbonate of soda is used largely in Great Britain in washing.

(*b.*) *More commonly*, however, it is in crystalline, *striated or channeled* masses, which, when of considerable length, are called stick nitre.

(*c.*) *Primitive form, a right rhombic prism*—incidence of the lateral planes, 109.50; ratio between one side of the base and the height, nearly : 1 : 0.48.

Cleavage, "parallel to all the faces of the primitive, and also to a plane passing through the two short diagonals of the bases.*

Nitre sometimes crystallizes in tables, or laminæ, and in the prism of six sides, the two opposite ones are commonly broad; the prism is sometimes terminated by 18 faces at each extremity, arranged in three rows, each having six faces, "as if three truncated pyramids were piled on each other." Sp. gr. 1.9603.

(*d.*) Taste, bitterish and cool.

(*e.*) Brittle, and easily pulverized.

CHIEF CHEMICAL PROPERTIES.

1. Action of heat.—*This salt is anhydrous*, and the small portion of water that is lodged mechanically between the plates of the crystals is easily dissipated by low ignition.

(*a.*) *It melts quietly into an oil-like liquid*, and if cooled, congeals into a smooth white mass.†

(*b.*) *If the heat be increased to redness, we obtain oxygen gas*, to the amount of about ⅓ of the weight of the nitre employed. The first portions are pure, but after about ⅓ part has been withdrawn, it is obtained more or less mixed with nitric oxide gas, and with nitrogen, which prevail most towards the end.

(*c.*) *If the heat be continued, the decomposition is entire*, and potassa remains behind. *If the salt be removed from the fire, when only a part of the oxygen gas has made its escape, it is found reduced to the state of nitrite.*

This is an easy process for oxygen gas, and answers very well, where we do not want it very pure. It is usually saved, when it is so good as to re-light a candle just blown out, but having a red wick.

In a gun barrel or iron bottle, the salt should be melted at the upper part first, and then the remainder by degrees; otherwise there is danger of an explosion. One pound of nitre yields about 1200 cubic inches of oxygen gas.

2. Action of water.

(*a.*) *Soluble in 7 parts of water at* 60° *Fahr.* and in nearly its own weight of boiling water;‡ crystallizes on cooling. When mixed with water *it sinks the thermometer* 19° *during its solution.* With ice it produces a still greater degree of cold. It is used in hot countries for cooling wine; and the same portion of salt by evaporating and crystallizing, may be used again and again.

---

* Levy, Quart. Jour, Vol. XV, 284, and Henry.

† When melted, it is sometimes poured into moulds, and sold in round lumps like bullets, under the name *Sal prunella*. In this state it is preferred by jewellers, for heightening the color of their wares.—J. G.

‡ According to Dr. Hope, it is soluble in 4 or 5 times its weight of water at 60.

3. ACTION ON COMBUSTIBLES.—*The phenomena are brilliant and instructive.*

(*a.*) *Action of charcoal.*—If into melted nitre, charcoal powder be thrown, it deflagrates; and if 3 parts of nitre be employed to 1 of charcoal, the action is very energetic.*

(*b.*) *The product of the detonation of charcoal and nitre is always carbonic acid gas, mixed with nitric oxide and nitrogen, and probably with oxide of carbon,* and carbonate of potassa remains. If ignited charcoal be held above melted nitre, it will burn with increased brilliancy, owing to the disengagement of oxygen gas.

(*c.*) *Action of sulphur.*—Thrown into a red hot crucible, in the proportion of 3 parts of nitre to 1 of sulphur, the latter burns away very completely and rapidly; *the products are sulphuric and sulphurous acid, sulphate of potassa, nitrogen and nitric oxide gas;* the theory is obvious. It has been already mentioned, that in the manufacture of sulphuric acid a small quantity of nitre, usually about $\frac{1}{7}$ or $\frac{1}{8}$, is added to the sulphur, and it was known only that the sulphur was thus made to burn in such a manner as to form sulphuric rather than sulphurous acid. Now it is known that the sulphur decomposes the nitric acid of the nitre, by attracting such a proportion of its oxygen as leaves nitric oxide, which is displaced by the sulphuric acid. The nitric oxide meeting with oxygen in the air, forms red nitrous acid vapor; in the mean time the greater part of the sulphur has become sulphurous acid; the floor of the leaden chamber is covered with water several inches in depth; so that aqueous vapor, sulphurous acid and nitrous acid, are present, in mixture. When the two latter are mingled in a dry state, there is no decomposition, but with the aid of water the nitrous acid transfers oxygen to the sulphurous acid and converts it into the sulphuric; it thus becomes again nitric oxide; again attracts oxygen and transfers it to the sulphurous acid; and thus it becomes a vehicle for oxygen between the atmosphere and the sulphurous acid. A small quantity of water enables the sulphurous acid and the nitrous to unite and form a crystalline solid, as appears when a drop of water is admitted into a globe containing the two agents in a dry state; the same thing is supposed to happen in the leaden chamber, and the abundant water on the floor decomposing this compound, enables the nitrous acid to oxygenize the sulphurous and form sulphuric, while the nitric oxide is again evolved, to perform the same function anew.* At Fahlun, in Sweden, they are enabled to manufacture sulphuric acid in small leaden chambers, by placing upon the floor flat glass vessels containing nitric acid, which is decomposed by the sulphurous acid gas, thus evolving nitric oxide gas and answering the purpose of nitre, which is here omitted. This mode is less economical than the common one, but it produces a purer acid, containing only .1 or .2 of foreign matter, consisting entirely of sulphate of lead, while the common acid contains .5 or .6 of foreign bodies.†

---

* The Alchemists performed this deflagration, in a series of tubulated receivers, connected with each other, and with a tubulated retort, into which, when red hot, they projected their mixture of charcoal and nitre, immediately closing the aperture of the retort; their apparatus often blew up, but it sometimes escaped, and they then carefully collected the liquid condensed in the receivers; this they called *clyssus of nitre*, and imagined that it possessed the most wonderful properties in alchemy.

4. **Gunpowder, &c.**

(*a.*) *History.*—First known to the Chinese; neither its European discoverer nor the period of the discovery is exactly ascertained; attributed to Roger Bacon and to Swartz, a German, in 1320.‡

(*b.*) *Composition.—Gunpowder is an intimate mixture of nitre, sulphur and charcoal;* the proportions vary in different manufactories, and for different purposes; but those employed in the Royal Mills of England, are 75 *nitre,* 15 *charcoal,* 10 *sulphur.*§ These are the proportions generally employed in other countries. The nitre, being the most expensive article, is sometimes stinted; this of course injures the quality of the powder. Common gunpowder often contains not more than .50 of nitre.‖

(*c.*) *Process in the Royal Mills of England.*—The ingredients are as pure as possible. The nitre is carefully purified. Common salt, uncombined potassa and sulphate of magnesia,¶ are the most common impurities, and cause the powder to deliquesce. The charcoal is made in ignited iron cylinders, and the sulphur must be free from acid. The ingredients are separately pulverized; then

---

* Ann. de Chim. Vol. LIX, and Davy's Elements, Am. ed. p. 1.

† Berzelius, Ann. de Chim. et de Phys. Tome IX, p. 162. The acid made near New York, contains only .1 or .2 of foreign matter.—J. T.

‡ Gunpowder was not known in Europe before the end of the thirteenth century, probably not before 1320; it was well known in the middle of the fourteenth century, and cannon were used in Germany before 1372; first used by the English at the battle of Agincourt, A. D. 1415. See Nicholson's Journal, 8vo. series.

§ In France		Sweden	Poland	Italy
75.	nitre,	75.	80.	76.5
9.5	sulphur,	16.	12.	12.5
15.5	charcoal,	9.	8.	12.5
100.		100.	100.	101.5

Dr. Watson's essays.

	Nitre.	*Charcoal.*	*Sulphur.*
At present, both in England and France, common powder contains - - - -	75	12½	12½
Shooting powder for the sportsman, - - - - -	78	12	10
Or, - - - - - - - - - - - - - - -	76	15	9
Powder for blasting in mines and quarries, - -	65	15	20
M. Bouchet's patent powder, - - - - - - -	78	12½	9½

The shooting powder is glazed by the mutual friction of the grains in a barrel, revolving on an axis; the proportion of nitre and charcoal is large, to insure its quick action.—*Gray's Op. Chem. p.* 495.

‖ Black, Vol. I, p. 432.

¶ Id.

mixed, moistened and pounded in mortars, or ground, to the consistence of a thick paste, by large wheels of stone or cast iron, shod with copper. This mass is granulated, by passing it through a series[*] of parchment or wire sieves, turned by cranks and covered by a heavy piece of wood, usually lignum vitæ, whose motion and pressure force the powder through, in the form of grains. It is next sifted, and then dried, in drawers with canvass bottoms, by hot cylinders or stoves of iron placed on one side of the apartment, of which the shelves occupy the other three; or, as now practised in some manufactories, by steam, or by warm air thrown in from another apartment.[†]

Gunpowder, although frequently injured by dampness, can be preserved a long time, as appears from the fact that, in 1782, "there were discovered, at Purfleet, (England,) some barrels of very small grained powder, manufactured by Sir Polycarpus Wharton, surveyor of the ordnance in Charles the second's reign."[‡]

(*d.*) *Theory of its combustion.—Gunpowder is merely a mechanical mixture;* no chemical action takes place between its ingredients at common temperatures.[§] *At a red heat the oxygen of the nitre acts on the sulphur and carbon,* with which it is intimately blended; *the combustion is therefore intensely rapid and violent,* and it happens equally in a vacuum, in a mephitic gas, or in a dry cavity under water, and quite independently of air or of any foreign aid. The sulphur produces a rapid combustion, the charcoal contributes largely to the formation of gas, and a good gunpowder cannot be made without both these combustibles. The power is produced by the sudden formation and disengagement of a vast volume of gases, greatly expanded by the heat.

Gunpowder, wet and crushed in the manner of a squib, may be safely although imperfectly burned in a gun or pistol barrel, and the gases may be caught in an air jar filled with water.—They are principally carbonic acid, nitrogen and nitric oxide; sulphurous acid gas and sulphuretted hydrogen, and some ammonia; perhaps also carburetted hydrogen and oxide of carbon. Sulphuric acid is produced and forms sulphate of potassa, which with some sulphuret, a little carbonate of potassa and charcoal, remains. The smell of sulphuretted hydrogen gas is perceived in fire arms, especially when in the act of being cleaned.

(*e.*) *The volume of gases produced from gunpowder is, at* 60°, 250 *times, and at the moment of discharge* 1000 *times, greater than that*

---

[*] Said to be, in the Royal Mills of England, 24 in number.

[†] For an account of the mode of making gunpowder in France, see Thénard, 5th ed. Vol III, p. 251.

[‡] Gray's Op. Chem.

[§] See Am. Jour. Vol. XVII, p. 132, where it appears that it may sometimes explode in consequence of the heat given out by sudden compression of air, if not of its own ingredients.

of the powder.[*] As each additional volume of gas exerts a force equal to that of the atmosphere, $1000 \times 15 = 15000$ pounds on a square inch, which will project a bullet with a force of 2000 feet in a second.[†] The general rule for powder for heavy shot is one third of the weight of the shot, for lighter artillery one fourth. Count Rumford found that 18 grains of gunpowder raised a weight of 18000 lbs. The goodness of gunpowder is judged of by the force with which it impels projectiles; it is measured in an instrument called an *eprouvette.* A rude analysis of gunpowder is easily effected by dissolving the nitre by water and then subliming the sulphur out of the charcoal.[‡]

(*f.*) *Pulvis fulminans or fulminating powder.*[§]—It is made of 3 *parts of nitre,* 2 *pearl ashes and* 1 *sulphur,* well dried and thoroughly mixed, by gentle trituration in a warm mortar. It is placed in a spoon and heated by a candle or the embers till it gradually blackens and melts, when it explodes, with a sharp and loud report. If the heat is raised too high or too rapidly, the powder is decomposed and does not explode.

(*g.*) *Theory.*—Similar to that of gunpowder, but the explosion happens only when all the mass is melted, and the gases are disengaged instantaneously, whereas the grains of gunpowder[‖] burn successively, although rapidly.* This powder has little effect on a ball when fired in a gun.

---

[*] Vide Robbins' Essay on Gunnery, and Nich. Jour. IV, 258.

[†] Murray.

[‡] For an accurate method by Gay Lussac, see Ann. de Ch. et de Phys. XVI, 434.

[§] This powder is used by sportsmen for priming, to insure the discharge of their fowling pieces. For this purpose it is slowly melted over the fire, care being taken to stir it frequently. When the fusion is complete, it is taken off and stirred until cool, which leaves it in the state of a fine powder. It must be kept in close vessels, since it rapidly attracts moisture from the atmosphere.

[‖] *Composition formerly used for firing artillery is* 60 *nitre,* 40 *sulphur and* 20 *gunpowder;* rammed into a small pasteboard cylinder.

Chinese blue lights for signals, 28 *nitre,* 7 *sulphur,* 2 *arsenic,* ½ *a part rice flour,* and water enough to knead them into a stiff paste; the water and flour retard the combustion; this paste is rammed into little earthen pots and kept in pitched cloths.

Fire balls to be thrown into an enemy's camp, 40 *nitre,* 15 *charcoal,* 3 *pitch and a little sulphur.*

It is not consistent with the object of this work to enter into the details of pyrotechny, which may be found in many works, Gray's Op. Chemist; Cutbush, in Am. Jour. Vol. VIII. p. 118, &c. The following may be taken as examples of preparations for rockets.

Powder for rockets.

Rockets of one or two ounces—8 parts gunpowder, 1 fine soft charcoal.

Somewhat larger—10 ounces gunpowder, 3½ saltpetre, 3 charcoal.

Of five or six ounces weight—37 ounces gunpowder, 8 saltpetre, 2 sulphur, 6 charcoal, 2 iron filings.

Ten to twelve ounces weight—17 ounces gunpowder, 4 saltpetre, 3½ sulphur, 1 charcoal.

One pound weight—16 ounces gunpowder, 1 sulphur, 3 charcoal.

Four to seven pounds weight—31 saltpetre, 4½ sulphur, 10 charcoal.

Still larger—8 pounds saltpetre, 1¼ sulphur, 2¾ charcoal.

The contents of a Congreve rocket, analysed by Gay Lussac, were in the proportion of 720 nitre, 16 charcoal and 234 sulphur. A rocket made upon this result had the same properties with the English.

(*h.*) *Another pulvis fulminans* has been recently proposed, consisting of *nitre 2 parts*, neutral *carbonate of potassa* 2, *sulphur* 1 *and marine salt* 6, all finely powdered. It explodes with great energy.†

(*i.*) *Phosphorus.*—If a mixture of *phosphorus and nitre be struck forcibly with a hot hammer, a violent detonation* takes place, and jets of flaming phosphorus dart out laterally with danger to the spectators. It is not a proper experiment before a class.

(*j.*) *Hydrogen gas.—If a stream of this gas be passed*, by a bent tube, *through melted nitre, the salt is decomposed with detonation*, and water formed; the experiment requires caution.

(*k.*) *Powder of fusion*—3 parts nitre, 1 sulphur, and 1 fine saw dust, thoroughly mixed. If this mixture is surrounded by a rim of sheet copper, and set on fire, the copper instantly melts, being converted at the same time into a sulphuret.

(*l.*) *White flux*—equal parts of nitre and crude wine tartar, mixed and deflagrated in a red hot crucible.

(*m.*) *Black flux*—1 part nitre and 2 tartar, deflagrated in the same manner; it is a mixture of carbonate of potassa and charcoal.

The substances, under *j*, *k*, and *l*, (especially the last,) are employed as fluxes, and for other purposes in small metallurgic operations.

5. Action of Acids.

Decomposed by phosphoric and boracic acids, aided by heat.

Muriatic acid with heat, evolves nitrous acid and chlorine, a mixture with which the alchemists, used to dissolve gold. (See chlorine.)

Sulphuric acid.—The action of this acid has been mentioned.

6. Composition.—*The equivalent of nitrate of potassa is* 102; it being an anhydrous salt, is composed of 1 proportion of dry nitric acid 54+ 1 proportion of potassa 48=102. For 100 parts, of the acid 52.94+ alkali 47.06=100.

In full detail, its constitution is,

Oxygen 5 proportions, $5\times8=40+$ 1 prop. nitrogen, $14=54$
Potassium 1 proportion, $40+1$ proportion oxygen, 8 $=48$

102

Thus we see how in a complex compound the numbers expressing the combining powers of all the principles are united, according to an admirable law.

---

* Vide Black's Lectures, 1, 438, note 32. The difference is seen when a train is fired on a board and another between two boards with weights upon them: the rapidity of the combustion is greatly increased by the reaction of the flame, as in the chamber of a gun.

† Ferussac's Bulletin, Aout, 1828.

7. SOURCES OF NITRATE OF POTASSA.

(*a*.) *There are some soils which contain so much of it that they are called saltpetre grounds.* In Italy and Spain, and in the latter especially, it is found, even in the dust of the roads; and when the crops of wheat fail, the farmers frequently obtain an indemnity, by lixiviating the soil for nitre.* In India, in China, and in the eastern parts of Persia, *saltpetre* earths are very common, and the salt even effloresces on the surface; and from these countries a great part of the nitre used in Great Britain and America is brought. It is found in pasture grounds, near Lima, in South America, and in Podolia, a province of Poland, in little hillocks, being the ruins of habitations, in a plain country, formerly populous.

(*b*.) *Nitre is usually found in places where there has been an accumulation of animal and vegetable matters*, or an abundance of animal effluvia, having free communication with the air, and with alkalies or lime; as in the ruins of old houses, in the earth of cellars, and stables, and in pigeon lofts, in which places it often effloresces, provided the walls be of lime, and in general in low situations, which have been frequently impregnated with animal or vegetable fluids in a putrescent state. Nitre is produced in grounds much trodden by cattle, and frequently impregnated with their excrements.—*Ure.* In such places the nitre is constantly reproduced, after being removed, especially if the place have a northern exposure. In France the richest part of the vegetable mould is often found to contain nitre,† and in this country, such sources were resorted to, to afford nitre during the war of the revolution. The earthy floors of the tobacco houses were found to be particularly rich in this salt.

(*c*.) *Nitre is also found in marly and calcareous grounds;* or rather another salt is found in such places, greatly resembling nitre, and into which it is easily converted.‡

(*d*.) *In the calcareous caverns of the Western and South Western States of the United States of America, there are vast resources for manufacturing nitre*, derived from the nitrate of lime, found in these caves. It is changed into saltpetre by wood ashes—one bushel of earth, in some instances, yielding from 3 to 10 pounds of the salt. In Kentucky, there are masses of ready formed nitre, mixed in sandstone rocks.

(*e*.) *In vegetables.—Nitre is found in borage, bugloss, parietaria, hemlock, and the sunflower; and in the dried branches of this last,*

---

* Black, Vol. II, p. 444.

† They prefer the earths that are at a little distance from the surface of the ground; they are distinguished by their sharp taste; it is a rich nitre ground that contains 5 per cent.

‡ The wells of great cities also afford this salt. In Peale's Museum, in Philadelphia, is deposited a quantity of nitre, obtained along with other salts, during the analysis of the pump water of that city.

as well as of other plants, it is sometimes found crystallized in needles. It exists in tobacco; and sometimes the stalks of this plant contain so much nitre that when dried, they will burn like a squib. The nitre in plants appears to be derived from the soil.

How is nitre formed?

(*f.*) *During the decomposition of bodies containing nitrogen, this principle has been supposed to combine with the oxygen of the air, to form this acid, and this unites with any proper base.*

Lime is often present, and forms in this manner nitrate of lime, which by a substitution of the alkali, from weeds, ashes, &c. is changed into nitrate of potassa.

(*g.*) *There seems great reason to believe that the atmosphere is, to a certain extent, converted by electrical agencies, into nitric acid,* as nothing more is necessary, than that the elements should unite in nearly the reversed proportions in which they exist in the air. There is a popular impression that thunder and lightning, and also clear frosty weather, are favorable to the production of nitre. That its production depends upon atmospherical phenomena, seems to be proved from the fact, that the lixiviated saltpetre earth becomes impregnated again in a year or or two, by exposure to the air.

(*h.*) *Artificial nitre beds.*—Most of the nitre used on the continent of Europe, is produced from composts, *formed of garden mould, lime rubbish, ashes, and marly earths, and animal and vegetable substances,* of every description. The bed is screened by a thatched roof, through which the air has access, although it does not circulate very freely. The heap is frequently stirred, and moistened from time to time with the drainings of the barn yards, and of the kitchen. To favor the process, situations are sometimes chosen on the declivities of hills. Moderate light, moderate moisture, a temperature from 65° to 90°, and (as asserted,) additions of common salt, promote the production of nitre.

8. Extraction.—*The nitrous earths, mixed with quick lime and ashes, are placed in large vats or barrels,* with perforated bottoms, covered with straw, and sometimes there is a second bottom, below the first, with a stop cock between. Water dissolves the nitrates, the ashes decompose the nitrates of lime and magnesia, and the nitrates of potash, and other soluble salts, are drawn off below. In the refining of nitre, eggs, milk, soap, and twigs of euphorbia, are used. The solution is then concentrated by heat, and suffered to crystallize. It is at first a dirty mass with many impurities, particularly common salt. From these it is purified by successive solutions, evaporations, and crystallizations. The earthy bases are precipitated by potassa, or ashes. Such salts as are less soluble than nitre, are separated during the evaporation, and such as are more soluble, are drawn off with the mother water. These operations are repeated three or four

times before the nitre is sufficiently pure for the manufacture of gunpowder.

9. Uses.—*Nitre*[*] *is an important substance.* It is nearly indispensable in the manufacture of the nitric and sulphuric acids. *In medicine* it is given as a diuretic, and cooling remedy; it is a powerful antiseptic, and is much used in the salting of beef, to the fibre of which it gives a fine red color, and great firmness.[†]

It is given only in inflammatory states of the body, 5 to 20 grains at a time, and not exceeding 1 or 1½ drachms in a day; it diminishes heat and vascular action, and is cathartic.

In a dose of an ounce, it is a violent poison, and has often been sold and given by mistake, for sulphate of soda. It can always be distinguished by throwing it on burning coals, when if genuine, it will deflagrate; and by the emission of fumes of nitric acid, when sulphuric acid is added to it.

In Chemistry, it affords oxygen gas; it imparts oxygen to many substances which cannot be made to combine with it in any other way, as to metallic titanium, which resists even nitro-muriatic acid. It is employed in metallurgic operations, in the assaying of ores, and it is used to determine, by deflagration, the proportion of carbonaceous or other combustible matter contained in a soil, in coal, &c. It has changed the whole art of war; and in naval conflicts, gunpowder is, and must remain, the principal means of annoyance.

NITRATE OF SODA.

1. Name and preparation.—*Formerly called cubic nitre*, from the obtuse rhomboidal form of its crystals. *It is prepared by saturating soda, or its carbonate, with nitric acid;* it is not known in the shops.

2. Properties.

(*a.*) *Taste more bitter than that of nitre*, but its general properties very similar.

(*b.*) Rather more soluble, *requiring only* 3 *parts of water at* 60°, *and less than its own weight at* 212°.

(*c.*) *Affected by heat, acids and combustibles, in the same manner as nitre*, but is less fusible.

(*d.*) *Slightly deliquescent*, and therefore unfit for making gunpowder.

3. Composition.—According to Dalton, 57.6 and 42.4 base, but Dr. Henry remarks that these numbers do not agree with equivalent proportions. On the authority of Wenzel, quoted by Brande,[‡] *it is*

---

[*] For the sake of brevity, I have generally, in this article, used the word *nitre* instead of *nitrate of potassa*.

[†] Muscular fibre after being thoroughly impregnated with salt, especially with the addition of nitre and dried, becomes nearly imputrescible. In the Leverian museum, in London, I saw beef in 1805, a remnant of the provisions with which Lord Anson performed his circumnavigation, from 1739 to 1744.

[‡] Tables of definite proportions.

composed of 1 *proportion of soda* 32, *and* 1 *of nitric acid* 54=86, *its equivalent.*

4. Uses.—Proust suggested that, for economy, it might be employed in artifical fire works, and that 5 *parts of it, with* 1 *of charcoal and* 1 *of sulphur, will burn three times as long as common gunpowder*, and of course make a more enduring exhibition. When thrown on a shovel full of burning coals it produces a peculiar orange yellow flame.

5. Natural sources.—It had been thought that this salt was unknown as a natural production, but it has been, within a few years, discovered in Peru, in the district of Atacama, near the port of Yquique; it is in strata of variable thickness, under clay, extending fifty leagues, and in some places it is quite pure. The proprietor had, at the date of the account, obtained from it 40000 quintals.*

NITRATE OF AMMONIA.

1. History and name.—Long known and *formerly called nitrum flammans and semivolatile.* Our accurate knowledge of its properties is derived, principally, from Berthollet and Davy.

2. Preparation.

(*a.*) Bring into contact, in a glass globe with two necks, the vapor of strong nitric acid and ammoniacal gas, (in an apparatus like that on p. 385,) when nitrate of ammonia will be precipitated, at first concrete, but which will soon deliquesce and then crystallize in prisms.

(*b.*) *The best mode is to saturate diluted nitric acid with concrete carbonate of ammonia;* evaporate with a gentle heat and crystallize.† If the evaporation has been performed between 70° and 100° Fahr. the crystals are hexahedral prisms crowned by long hexahedral pyramids; if at 212°, they are in silky fibres; if at 300°, the solution concretes without crystallization.

3. Properties.

(*a.*) *Taste, bitter and cool. Sp. gr.* 1.5785.

(*b.*) *Soluble at* 60°, *in twice, and at* 212°, *in half its weight of water;*‡ deliquescent.

(*c.*) *The acids*, especially the *sulphuric*, decompose it.

The fibrous or *prismatic crystals melt at* 230°, or below 300°; ebullition, but without decomposition, commences between 360° and 400°; *decomposition begins at* 450°, *and between that and* 500°, *it affords the pure protoxide of nitrogen.*

---

* Ann. de Chim. et de Phys. XVIII, p. 442, and Thénard, III, 265.

† A few embers, under an earthen dish, are sufficient: hot coals would volatilize and decompose the salt. The common aquafortis need not be diluted. The solution is in a good state to crystallize, when a twitching pellicle forms on the surface, and when a knife blade dipped in the solution and waved in the air is speedily covered with small crystals.

‡ Dr. Hope says, that it dissolves at 60°, in its own *weight of water, and generates* 46° *of cold.*

(*d.*) *The compact nitrate suffers no change below* 260°; from 275° to 300°, it sublimes slowly, without suffering decomposition or becoming fluid; at 320° it melts, and *from* 340° *to* 380°, *is decomposed* partly sublimed, and yields the above mentioned gas.[*] *If the temperature does not rise above* 500°, *the salt is wholly decomposed* and converted into nitrous oxide and water, in the proportion of about 3 parts of gas to 1 of water.

100 *grains of the salt afford* 84 *cubic inches of the gas.*

The hydrogen of the ammonia, with one proportion of the oxygen of the nitric acid forms water; the remainder of the oxygen and of *the nitrogen,* forms *the nitrous oxide gas.*

(*e.*) *At* 600° *and above, this salt explodes by the reaction of its own elements,* being converted into nitrous acid, nitric oxide gas, water and nitrogen gas.

(*f.*) *On red hot iron or any other ignited body, it deflagrates* beautifully with a rich yellow flame, and exhibits a singular instance of a burning saline body; the reaction of the oxygen of its acid with the hydrogen of its base, produces the rapid combustion. Hence its old name of *nitrum flammans.*

4. Uses.—*They are limited to the formation of nitrous oxide, and to some cases in chemistry,* when we wish, by heat, to oxidize substances, and to have no residuum; the nitrate of potassa always leaves that alkali free or combined, but the nitrate of ammonia when deflagrated, leaves nothing behind.

5. Alkalies and earths.—Baryta, strontia, potassa, soda, and lime, by trituration in the cold, attract the acid and liberate the ammonia.

6. Equivalent number and composition.—This salt is composed of acid, 1 proportion, 54, ammonia, 17=71, for the dry salt, and according to Berzelius, 1 proportion of water 9, for the prismatic variety, =80.

The proportions of Berzelius, are for the 100 parts—acid, 67.625, base, 21.143, water, 11.232=100.00[†]

The composition according to Davy, is for the

Prismatic crystals,	69.5	Fibrous,	72.5	Compact,	74.5, acid.
" "	18.4	"	19.3	"	19.8, ammonia.
" "	12.1	"	8.2	"	5.7, water.
	100.		100.		100.

---

[*] According to my experience, the compact nitrate, if not very carefully dried, (which is difficult on account of the fluid imbibed by its pores,) is apt to puff up in the retort, with a violent effervescence of aqueous vapor; while the dry prismatic nitrate is perfectly manageable, and is decomposed with great steadiness and uniformity.

[†] Ann. de Chim. T. LXXX, p. 182.

NITROUS OXIDE—PROTOXIDE OF NITROGEN.

Remarks.—It has already been stated that *this oxide has been reserved for the present place, because it will be best understood in connexion with the salt from which it is always obtained.* Otherwise it would naturally have been introduced after nitrogen and before its deutoxide, the nitric oxide gas.

1. History.—*Discovered by Dr. Priestley,* in 1772, by whom it was called dephlogisticated nitrous air; *Mr. Davy examined it with more particular care,* and called it nitrous oxide.

2. Preparation.

(*a.*) *The nitric oxide can be converted into the nitrous oxide,* by the action of various substances which will abstract half the oxygen; they will be mentioned in an appendix to this article.

(*b.*) But the only eligible method is *by the decomposition of the nitrate of ammonia by heat.**

(*c.*) *The solid nitrate, which should be as dry as possible, should not fill more than one quarter the body of the retort*—a good Argand's lamp or a few live coals are sufficient for the decomposition, which is known to be proceeding well, when the melted materials boil quietly and emit small bubbles; a thin snowy vapor revolving in the retort, and no red fumes appearing. If the heat is raised too high, the bubbles will be very large, and a reddish tinge in the retort will indicate the formation of nitrous acid vapor.

3. Theory of the decomposition and equivalent number.

(*a.*) *The nitrate of ammonia is composed entirely of the ponderable part of gases, and* the effect of the heat is so to rearrange them, by the exertion of new affinities, that the solid *is converted, wholly, into aërial products; steam, and nitrous oxide.*

(*b.*) *The nitrate of ammonia is composed of one proportion of nitric acid* 54, *and one of ammonia* 17=71.

The acid is composed of nitrogen, 1 *proportion,* 14, *and oxygen,* 5 *proportions,* 8×5=40=54.

The alkali consists of nitrogen, 1 *proportion,* 14, *and hydrogen,* 3 *proportions,* 1×3=3=17.

(*c.*) *The representative or equivalent number of nitrous oxide is* 22, *made up of* 1 *proportion of nitrogen* 14, *and* 1 *of oxygen,* 8=22.

(*d.*) During the decomposition, 71 *grains of the salt afford* 27 *of water, consisting of* 3 *proportions, viz.* 9×3, *and water is composed of* 1 *proportion of hydrogen* 1, *and* 1 *of oxygen,* 8=9; *there are produced also,* 44 *grains of nitrous oxide, consisting of two proportions, or* 22×2.

---

* In addition to what has been already said under the nitrate of ammonia, we will observe that, notwithstanding the statements under 2, (*c, d,* and *e,*) *it is not necessary to use a thermometer to regulate the decomposition of this salt.*

The three proportions of water consist of oxy. 24+*hydrog.* 3=27
two " *nitrous oxide* 16+*nitrog.* 28=44
—
71[*]

(*e.*) This view supposes the nitrate of ammonia to be anhydrous, and all the water that appears during the decomposition, to be generated and not evolved.

It is a beautiful example of the arrangement of principles in definite proportions, so that with a complete decomposition and a formation of new products, there is no loss.

4. PROOFS OF THE PURITY OF THE GAS.

(*a.*) ***When the mouth is applied to a bottle of it, a distinctly sweetish taste is perceived,*** without any corrosiveness or peculiar smell.[†]

(*b.*) *Entirely absorbed by agitation with about its own volume of water*, that has been previously boiled, and become cold without the access of air. *The saturated water will have a sweetish taste, and faint agreeable odor*, and the gas will be expelled, unaltered, by boiling; the solution does not redden the vegetable blue colors, or produce any exhilirating effects.

(*c.*) *No red fumes are produced by mingling this gas with oxygen gas or common air*, which would happen if nitric oxide gas were present;

(*d.*) Nor, on the other hand, does nitric oxide gas produce any change of color or absorption, as it would do if free oxygen gas were mingled with it.

(*e.*) *It is not diminished by agitation with green sulphate of iron*, which would be the fact if nitric oxide were present.

(*f.*) It is not acid.

5. PHYSICAL PROPERTIES.

(*a.*) Colorless—transparent.

(*b.*) Specific gravity, 1.5277, common air being 1.

(*c.*) Weight for 100 cubic inches of the gas at medium temperature and pressure, 46.596; this appears also from its constitution, which is nitrogen 100 cubic inches, weighing 29.652 grains, and oxygen, 50 cubic inches, weighing 16.944 grains, =46.596,[‡] the 150 volumes of gases being condensed into 100.

---

[*] Turner.

[†] Provided it has stood long enough over water to absorb any saline or acid vapor, for which one hour and sometimes half an hour is sufficient.

[‡] Dr. Prout, as has been already observed, introduced the rule that the atomic or representative number of a gas multiplied into the specific gravity of oxygen, if that be unity, or of hydrogen, if that be unity, will give the specific gravity of the gas in question—thus, if oxygen be unity, then the representative number of nitrous oxide is 2.75 and 2.75 × by .555 =1.526 or the equivalent hydrogen being unity, is 22, which × .0694 = 1.526.

6. Action of combustibles.

(*a.*) *A lighted candle burns, with increased brilliancy in this gas*, and with a white flame, which, before extinction, appears edged with blue.

(*b.*) Dr. Turner states, that an extinguished candle retaining "a red wick," is lighted again by immersion in this gas.*

(*c.*) *Sulphur burning with a blue flame, is immediately extinguished;* but *with a white flame*, that is, at a higher temperature, *it burns vividly*, and the flame becomes rose-colored.

(*d.*) *Phosphorus may be melted*, and if touched with a red hot wire, *it may be even sublimed in this gas without burning;* but if touched with a white hot iron the phosphorus burns almost explosively.

The jar should be strong, not more than one eighth filled with the gas, and the wire well curved, so that it may be expeditiously withdrawn; not unfrequently the jar bursts in the experiment. The combustion ceases when about one half the gas is consumed, and the product is phosphoric acid, nitrogen being evolved.

(*e.*) If the *phosphorus be already on fire* when it is introduced, it *continues to burn but with increased splendor*, greater than we should infer from the proportion of oxygen which the gas contains.

(*f.*) *Charcoal, vividly ignited, is said to burn in this gas* more brilliantly than in common air,† and if properly managed to produce, for each measure of nitrous oxide, one of nitrogen, and half a measure of carbonic oxide, equivalent to half a measure of oxygen.‡

(*g.*) *Hydrogen gas, mingled, volume for volume with this gas, explodes by the contact of flame*, and by its acid, the nitrous oxide is decomposed by spongy platinum at the common temperature.

With 40 hydrogen to 39 nitrous oxide, there remains only nitrogen, and if the proportion of hydrogen is smaller, some nitric acid is produced.§ In general, the products of the combustion of hydrogen in nitrous oxide, are the same as in oxygen, or in common air, and nitrogen remains equal in volume to the original gas.

(*h.*) *Pyrophorus does not take fire spontaneously in this gas*, but it takes fire if touched with an iron strongly heated, but not to ignition. It is the only body which burns in this gas, at a temperature below ignition.

(*i.*) *Phosphuretted hydrogen flashes in this gas.*

(*j.*) Potassium and sodium decompose it below a red heat, evolving nitrogen, and forming alkali.

---

* This has never succeeded with me.

† In this experiment I have never been able to succeed.

‡ Henry. § Ibid.

(*k.*) "*An iron wire burns in this gas nearly as well as in oxygen gas.*"

7. COMPOSITION.

(*a.*) The equivalent number of this gas has been already stated to be 22.

(*b.*) As two volumes of nitrous oxide require, for decomposition, two volumes of hydrogen, which can saturate only one volume of oxygen; it follows that the residuary nitrogen, which is found to be expanded into two volumes, was combined with 1 measure of oxygen, and that the three were condensed into two; or one volume of nitrogen combines with half a volume of oxygen, and the volume and a half occupy one volume, as before stated under specific gravity; one volume of nitrogen, or 1 proportion, is 14, and half a volume of oxygen is 8, and $8+14=22$.

(*c.*) *Ammoniacal gas* 100 *measures*+150 *nitrous oxide, produce a combustible mixture*; the oxygen of the oxide uniting with the hydrogen of the ammonia.

(*d.*) *Olefiant gas burns, when mingled with this gas and ignited.*

(*e.*) *Carbonic oxide* 1 *vol.* +*nitrous oxide* 1 *vol. fired by the electric spark, over mercury, produce* 1 *vol. carbonic acid, and* 1 *vol. of nitrogen.*

This method of analysing nitrous oxide was introduced by Dr. Henry.*

Let 100 measures of nitrous oxide, proved, by agitation with green sulphate of iron, to be free from nitric oxide, be fired with a slight excess, say 110 or 115 measures of pure carbonic oxide,† and 100 measures of carbonic acid will be obtained.

(*f.*) *If this gas be electrized* in a tube over mercury, it is partially decomposed, being converted into nitrous acid, and common air, and a similar effect is produced by passing it through a thoroughly ignited porcelain tube, glazed within and without.

8. CONDENSATION OF NITROUS OXIDE.

(*a.*) *Effected by Mr. Faraday,‡ by means similar to those that have been already described* in the case of other gases. Some nitrate of ammonia, rendered very dry, by a partial decomposition by heat, in the air, was placed in the end of a recurved tube, sealed at both extremities; the end containing the salt was then heated, while cold was applied to the other end, by a mixture of ice and snow.

(*b.*) *Two fluids were obtained, the one water, with a little nitrous acid and oxide, and the other, floating upon it, being very mobile, limpid, and colorless, was the liquified nitrous oxide.*

---

* Ann. of Phil. N. S. Vol. VII, p. 299.

† Previously washed with a solution of caustic potash.

‡ Phil. Trans. 1823, p. 195.

(*c.*) *It was so volatile*, that the warmth of the hand, although under so great a *pressure*, converted it into vapor, *and it boiled readily by the difference between* 0 *and* 50°. In refractive power it was inferior to any known fluid, not excepting even the other condensed gases. *It remained fluid at* −10°. *When the tube was opened in the air, the fluid instantly burst into gas, and another tube being opened under water, the fluid rushed again into the form of gas*, which was collected.

(*d.*) To estimate the pressure, a trumpet shaped capillary tube, containing a globule of mercury, after being graduated, by the passage of the mercury through the different parts of the tube, was sealed at one end, and introduced into the larger tube, before it was closed. The movement of the mercury indicated the pressure, and when it became stationary, the force, at 45°, *appeared to be equal to* 50 *atmospheres, and* $50 \times 15 = 750$ lbs. upon the square inch. At 32° the pressure was 44 atmospheres, and $15 \times 44 = 660$ pounds on the square inch; 12 degrees of temperature having added to its pressure 7 atmospheres, or 105 pounds, or nearly 9 pounds for each degree. Mr. Faraday always subtracted 1 atmosphere for the air in the tubes when the experiment began.

9. EFFECTS ON ANIMAL LIFE.

(*a.*) *Warm blooded animals*, confined in nitrous oxide *speedily die*,[*] and fishes expire in water impregnated with it.[†] For many years after its discovery, no suspicion was entertained that it was respirable.

(*b.*) *This gas is not only respirable, but it is the most powerful stimulant known.*[‡]

(*c.*) *This was first ascertained by Sir H. Davy*, in a series of trials on respiration, some of them very hazardous, which he made upon his own person; the results may be found in his Researches, from which the following passage is extracted, p. 487.

"Having previously closed my nostrils, and exhausted my lungs, I breathed four quarts of nitrous oxide from and into a silk bag. The first feelings were similar to those produced in the last experiment, (giddiness); but in less than half a minute, the respiration being continued, they diminished gradually, and were succeeded by a sensation analogous to gentle pressure on all the muscles, attended by a highly pleasurable thrilling, particularly in the chest and the extremities. The objects around me became dazzling, and my hearing more acute. Towards the last inspiration the thrilling increased, the sense of muscular power became greater, and at last an irresistible propensity to laughter was indulged in; I recollect but indistinctly what followed; I know that my motions were various and violent. These effects soon ceased after respiration. In ten minutes I had recovered my natural state of mind. The thrilling in the extremities continued longer than the other sensations."

---

[*] Dr. Ure, (Dict. 2d Ed. p. 619,) says that mice die more speedily than when immersed in nitrogen, hydrogen, or carbonic acid.

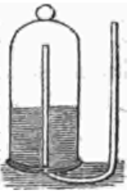
[†] The blood acquires a purple color in consequence of the respiration of this gas, and after death the muscles of animals are found to have lost their irritability.

[‡] It is said that if a little sulphate or muriate of ammonia be mixed with this nitrate, this salt will not afford an exhilirating gas.—*Ure.*

(*d.*) "The effects of the nitrous oxide on the human system are analagous to a transient, peculiar, various, and generally very vivacious ebriety."—*Dr. Hare.*

(*e.*) *It differs from all other diffusible stimuli* in not being attended by any subsequent depression; in general, on the contrary *the violent effects gradually subside into cheerfulness,* and manifest themselves by gayety and activity, which sometimes continue for hours, and even in particular cases for days.

(*f.*) *The general dose is from* 4 *to* 6 *or* 8 *quarts of the gas.*



(*g.*) It is breathed into and from a silk bag, or an air jar furnished with a stop cock, of a wide bore, or with a large bent tube, as in the annexed cut: and the action of the lungs may be relieved by having an assistant to hold the jar over the well of the pneumatic cistern, so that it may rise and fall; a small gasometer is still more convenient.

(*h.*) *The effects are not always agreeable. Some persons are not excited, but are rather depressed, and also fatigued,* by the constrained mode of breathing. *Some become faint and fall as in a fit or swoon;* but they in general soon recover, as if from a troubled dream or a turn of nightmare; *some are rendered apparently, apoplectic, and others are thrown into a temporary, but often violent delirium,* and in such cases the subsiding feelings are disagreeable.

(*i.*) *There is good ground for caution, and it would now be proper that the practice of breathing the nitrous oxide should be discontinued, except for medical purposes.*[*]

Remark.—Although we can offer no satisfactory theory to account for the action of the nitrous oxide, it cannot but be regretted, that so powerful a stimulus both of our physical and inellectual powers should remain a subject of mere curiosity or merriment. Differing from every other stimulus, in not producing depression correspondent to the excitement; why should it not be employed as a general tonic and as a comforting reviving remedy? In cases of great debility, it clearly ought not to be used in such doses, as to produce violent effects, but rather such as are gentle and longer continued, which might then be more frequently renewed. It would be proper to begin with diluting the gas one half or more, with common air, and the strength and quantity might thus be graduated to the state and strength of the patient. A larger gasometer being employed, the desired dose might be drawn off into a smaller one, and the gases being used over the same water, there need be no loss by absorption. In the American Journal, Vol. V, p. 196, may be seen an account of a person whose health of body and mind was restored by the respiration of this gas; and although it was attended by the singular circumstance, that he had acquired suddenly such a taste for sweets, that he craved sugar and molasses on all his food, even that of an animal kind, and this taste was freely indulged, still his health was permanently invigorated, and the acquired taste gradually left him.*

---

[*] Among multitudes to whom I have administered this gas, about 6 out of 8 have been agreeably affected; but there has been very great variety in the appearances, influenced, in most cases, apparently, by the physical and moral temperament of the subject. I have seen not a few cases attended by symptoms so violent and alarming that I have been very glad when they have subsided. *I have personally known no instance of fatal effects,* either immediate or remote; but some have thought themselves injured for a considerable period, and it has always been a subject of anxiety lest some *idiosyncrasy* should produce an unhappy termination. The experience of Thénard, Vanquelin, and their companions was altogether painful. See Thénard's Chem.

---

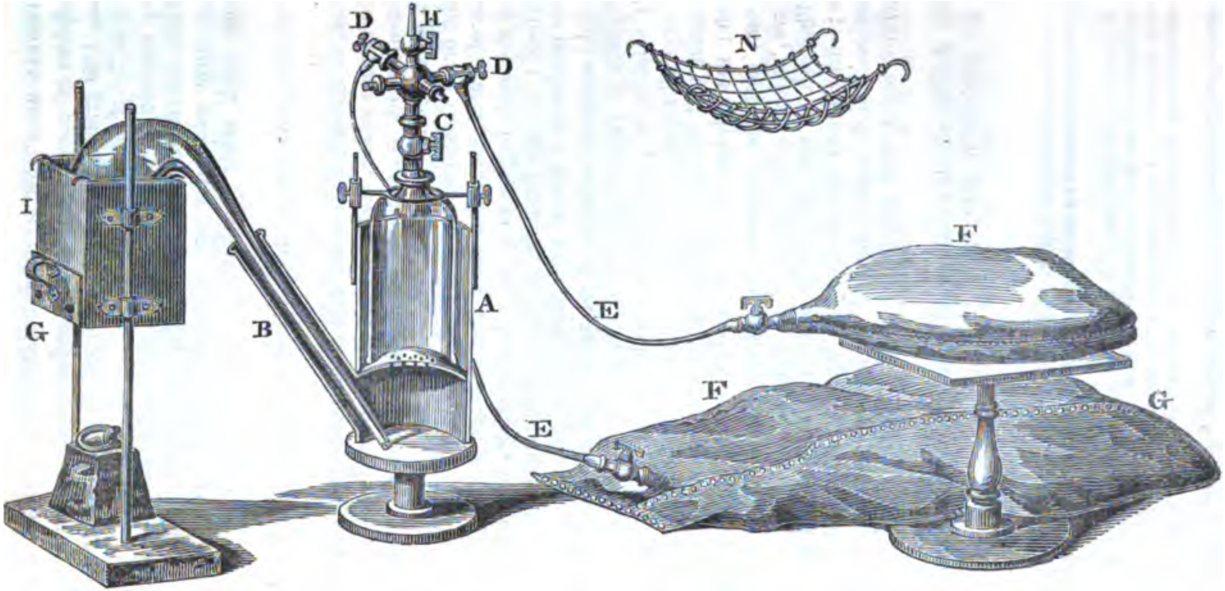
* *Apparatus for evolving and preserving nitrous oxide gas.—Dr. Hare.*

A, represents a copper vessel of about 18 inches in height, and nine inches in diameter, which is represented as being divided longitudinally in order to show the inside. The pipe, B, proceeds from it obliquely, as nearly from the bottom as possible.

Above that part of the cylinder from which the pipe proceeds, there is a diaphragm of copper, perforated like a cullender. A bell glass is surmounted by a brass cock, C, supporting a tube and hollow ball, from which proceed, on opposite sides, two pipes, terminating in gallows screws, D D, for the attachment of perforated brass knobs, soldered to flexible leaden pipes communicating severally with leathern bags, F F. The larger bag, is capable of holding about fifty gallons, the smaller one about fifteen gallons.

The beak of the retort must be long enough to enter the cylinder, so that the gas in passing from the mouth of the beak, may rise under, and be caught by the diaphragm. This is so hollowed as to cause it to pass through the perforations already mentioned, which are all comprised within a circle, less in diameter, than the bell glass. The gas is, by these means, made to enter the bell glass, and is, previously to its entrance, sufficiently in contact with water, to be cleansed from the acid vapor which usually accompanies it. On account of this vapor, the employment of a small quantity of water to wash the gas, is absolutely necessary; and for the same reason, it is requisite to have the beak of the retort so long, as to convey the gas into the water, without touching the metal; otherwise, the acid vapor will soon corrode the copper of the pipe, B, so as to enable the gas to escape. But while a small quantity of water is necessary, a large quantity is productive of waste, as it absorbs its own bulk of the gas. On this account, I contrived this apparatus, in preference to using gazometers or air holders, which require larger quantities of water.

The seams of the bags are closed by means of rivets, agreeably to the plan of Messrs. Sellers & Pennoch for fire hose. The furnace is so contrived, that the coals, being situated in a drawer, G, may be partially, or wholly removed, in an instant. Hence the operator is enabled, without difficulty, to regulate the duration or the degree of the heat. This control over the fire, is especially desirable in decomposing the nitrate of ammonia, as the action may otherwise become suddenly so violent, as to burst the retort. The iron netting, represented at N, is suspended within the furnace, so as to support the glass retort, for which purpose it is peculiarly adapted. The first portions of gas which pass over, consisting of the air previously in the re-


D
H
D
N
C
I
F
A
E
G
B
F
G
E

APPENDIX RELATING TO NITROUS AND NITRIC OXIDE GAS.

1. Sulphite of potash, pulverized and retaining its water of crystallization, 100 grains, in 1 hour, reduced 16 cubic inches of nitric oxide gas to 7.8 of nitrous oxide.

2. Dry muriate of tin, dry alkaline sulphurets and iron filings, in a few days, convert the nitric oxide gas into nitrous oxide.

3. Dry nitric oxide gas and dry sulphuretted hydrogen, slowly decompose each other; sulphur is deposited and nitrous oxide formed.

4. In all the above cases, the presence of water aids the decomposition.

5. Zinc, in contact with water and nitric oxide gas, converts the latter into nitrous oxide, and ammonia is also produced.

6. Nitrous oxide is produced during the solution of several of the metals in nitric acid.

7. Zinc or tin dissolved in nitric acid, diluted with five or six times its weight of water, gives this gas; zinc in large pieces gives nitrous oxide, till the acid begins to be of a brown color, when nitric oxide gas is formed; the gas from the solutions of the metals is never pure.

8. Iron produces it mixed with nitric oxide gas.

9. A cold saturated solution of nitrate of iron gives out much of it.

10. Nitrate of zinc, distilled to dryness—the same.

11. If sulphite of potash, mixed with caustic potash, retaining its water of crystallization, be immersed in an atmosphere of nitric oxide gas, the latter will become nitrous oxide and this will combine with the potash; the sulphate of potash and remaining sulphite are crystallized out, and the compound of nitrous oxide and potash is obtained pure, except some carbonate of potash.

12. This salt is very soluble in water; is caustic and pungent to the taste; turns green the alkaline test liquors, and contains about $\frac{1}{4}$ nitrous oxide, which is not expelled by boiling; powdered charcoal mixed with it burns with scintillation, and all acids expel the nitrous oxide.

13. By similar means a compound with soda may be formed, employing the sulphite of soda, &c.

---

tort, are to be allowed to escape through the cock, H. As soon as the nitrous oxide is evolved, it may be detected by allowing a jet from this cock, to act upon the flame of a taper.

To obtain good nitrous oxide gas, it is not necessary that the nitrate of ammonia should be crystallized; nor does the presence of a minute quantity of muriatic acid, interfere with the result. I have employed advantageously in the production of this gas, the concrete mass formed by saturating strong nitric acid, with carbonate of ammonia.

The saturation may be effected in a retort, and the decomposition accomplished by exposing the compound thus formed to heat, without further preparation.

NITRATES OF THE EARTHS.

General characters.

1. Similar to those of the nitrates of the alkalies, but their action on ignited combustible bodies is less vigorous; they rather scintillate than deflagrate on burning coals, but are eventually decomposed both by heat and by hot combustibles.

2. In some of them, as the nitrates of strontia and baryta, the acid is decomposed at once into nitrogen and oxygen, without the formation of a nitrite; the base being left behind.

3. Sulphuric acid evolves the nitric acid.

4. Only two of the earthy nitrates* are found native, the rest being formed by art.

NITRATE OF BARYTA.

1. DISCOVERY.—First formed by Scheele and Bergman, in 1776.

2. PREPARATION.

(*a.*) *By decomposing the carbonate of baryta*, native or artificial, *by the nitric acid*, diluted with from 8 to 16 times its volume of water; the effervescence is moderate.

(*b.*) *By decomposing, by the nitric acid, the artificial hydro-sulphuret of baryta*, formed from the decomposition of the sulphate by charcoal; or, a carbonate may first be formed by precipitating the baryta from the solution of the sulphuret by the carbonate of an alkali, and then this may be decomposed by nitric acid.

3. PROPERTIES.

(*a.*) *Crystals are easily obtained from the evaporated solution;* primitive form, the octahedron—sometimes in brilliant triangular plates, with truncated angles; sometimes grouped in stars.

(*b.*) *Sp. gr.* 2.9. *Taste, sharp and acrid.*

(*c.*) *Insoluble in alcohol, but soluble in* 12 *parts of water* at 60°, and in about 3 or 4 at 212°. Least soluble of all the nitrates; nitric acid being poured into a concentrated solution of muriate of baryta, causes a precipitate of the nitrate which more water redissolves.

Solution of nitrate of baryta should not cause a precipitate with nitrate of silver.

(*d.*) *Air produces little change upon this salt.*

(*e.*) *Decrepitates and feebly scintillates on burning coals.*

(*f.*) Decomposed by ignition in a crucible, and affords *pure baryta*,† by a theory already explained. If decomposed in a porcelain retort, by a regulated heat, the deutoxide may be ob[illegible]ed. (See note, p. 215.)

---

* Those of lime and magnesia.

† If the heat is urged too far, it vitrifies in an earthen crucible.

(*g.*) *Strength of affinity.*—Not decomposed by any single base or acid, except by the sulphuric and the phosphoric; decomposed by all the soluble sulphates, and by the carbonates of the alkalies.

4. Proportions.—This salt is anhydrous. If it is a compound of 1 proportion of nitric acid, and 1 of baryta, its composition should be

baryta,	-	78,	per cent. -	58.4
nitric acid,	-	54,		41.6
Its equivalent,		132		100.

From this result, the analyses of several of the most eminent chemists are not very remote.

Clement and Desormes,	40	acid,	60	base.
Jas. Thomson,	40.7		59.3	
Berzelius,	41.54		58.46*	

5. Use.

(*a.*) *To afford pure baryta* by its decomposition by heat.

(*b.*) *To detect sulphuric acid.*—In examining the nitric acid for this purpose by the nitrate of baryta, the latter must be dilute unless the former is so, otherwise the strong nitric acid will precipitate crystals of nitrate of baryta, presenting a false indication of impurity; their ready solubility in more water will however distinguish them.

Remark.—After the expulsion of the nitric acid by the compound blowpipe, the earth of this salt, if urged by the heat, exhibits on charcoal a deep yellow flame, and ultimately melts.

NITRATE OF STRONTIA.

1. Discovery.—By Dr. Hope, of Edinburgh.

2. Preparation.

(*a.*) *By dissolving carbonate of strontia,* 1 *part, in nitric acid* 1, *and water* 1; the action is rapid; carbonic acid is disengaged, and the nitrate of strontia, being evaporated over a lamp, the crystals precipitate during the process.

(*b.*) *By decomposing the sulphate of strontia by ignition with charcoal*—and then decomposing the resulting sulphuret by nitric acid; or it may first be turned into a carbonate by a carbonate of an alkali.

3. Properties.

(*a.*) *The crystals are octahedra or six sided prisms.*†

(*b.*) *Taste pungent* and cooling.

(*c.*) *Sp. gr.* 3.

---

* Quoted by Henry.

† See Ann. of Phil. N. S. VII, 288.

(*d.*) *At* [illegible]°, *dissolves in* 1 *part of water*, and at 212°, in somewhat more than half its weight.

(*e.*) *Alcohol does not dissolve it.*

(*f.*) *Deliquescent in moist air;* efflorescent in a dry air.

(*g.*) *Slightly scintillates on burning charcoal,* but with sulphur and charcoal in the proportions of gunpowder, it burns slowly and emits p[illegible] sparkles, and a fine green flame.

(*h.*) [illegible]mposed by ignition, and pure strontia remains.*

(*i.*) *A crystal in a burning candle produces a beautiful blood red flame.*

(*j.*) The flame of boiling alcohol also acquires a red color from this salt.

(*k.*) *Decomposed by the sulphuric and muriatic acids, and by baryta, potassa, and soda.*

4. PROPORTIONS.—According to Richter, this salt contains, (exclusively of water,) acid 51.4+48.6, base. Stromeyer gives acid 50.62+49.38, base. These proportions agree with the equivalent weight of the acid 54, and of the base 52.—*Henry.*

5. USE.—To afford pure strontia, and as a test for sulphuric acid; it is to be used with the same precautions as the nitrate of baryta.

NITRATE OF LIME.

1. NATURAL SITUATIONS.—*In the nitre beds; in the nitrous earths,* and particularly *in* those of *the caverns in the limestone of the western* American States; in the calcareous cement and plaster of old buildings that have long been inhabited. Its origin, as regards the acid, appears to be from the atmosphere, aided at least in some cases, by nitrogen from animal effluvia.

2. PREPARATION.

(*a.*) *By dissolving lime or its carbonate in nitric acid,* diluted with 5 or 6 parts of water, evaporating to a syrupy consistence, and then allowing it to cool and crystallize. 63 parts of carbonate of lime are decomposed by 90.23 of nitric acid of the density 1.5 and produce 103.05 parts of dry nitrate of lime.

3. PROPERTIES.

(*a.*) *The crystals are six sided prisms,* very acutely terminated; more frequently it is in fine brilliant needles.

(*b.*) *Taste acrid and bitter.*

(*c.*) *Sp. gr.* 1.6. *Suffers the aqueous fusion; if kept melted for five or ten minutes and then poured into a heated iron pot, it becomes phosphorescent,* and was formerly called Baldwin's phosphorus.†

---

* If at the instant of decomposition, a combustible substance be brought into contact with it, a deflagration with a very vivid red flame is produced. Dr. Hope.

† From the discoverer, *Baldwin,* who published an account of this fact in 1675.

It is to be broken up and preserved in tight bottles. After "being exposed to the sun for a few hours, it emits in the dark a beautiful white light."—*Henry.*

(*d.*) *With a strong heat it is completely decomposed*, and lime remains.

(*e.*) It contains so much water that *it scarcely acts on combustibles* unless previously dried.

(*f.*) *More deliquescent than any other salt.**

(*g.*) *Water at* 60° *dissolves* 4 *parts;* boiling water any quantity; and boiling alcohol its own weight. Although difficult to crystallize, it will, when evaporated to a thickish consistence, often become solid and hot by the slightest agitation.

(*h.*) *Acids, and alkalies and earths* decompose it in the same manner as the other nitrates. If potassa is added to a concentrated solution it throws down the lime nearly solid, because it absorbs the water.

4. Proportions.

Exclusive of water, the equivalent number of nitrate of lime would be 82, i. e. acid 54, lime 28, and this would give for its constitution in the 100 parts,

Acid	65.86	Mr. Dalton found acid		61.3	base 38.7
Base	34.14	Philips	"	65.6	34.4
	100.00				

The result of Mr. Philips is very near to the regular constitution. —*Id.*

NITRATE OF MAGNESIA.

(*a.*) *Of very little importance;* exists in the mother waters of nitre, and it *may be formed synthetically; crystallizes in minute needles* or in rhomboidal prisms; *its taste is very bitter;* sp. gr. 1.73; *soluble in half its weight of water at* 60°, *and in less at* 212°; *deliquescent; suffers the aqueous fusion;* by more heat is decomposed, like the other nitrates, leaving magnesia.

(*b.*) *Emits nitrous fumes with sulphuric acid.*

(*c.*) *The alkalies precipitate the magnesia.*

(*d.*) *Action on combustibles very feeble;* it only scintillates slightly on burning charcoal.

(*e.*) *Composition.*—According to Dr. Thomson, acid 1 proportion, 54; 1 of base 20; 6 of water 54=128, its equivalent, which gives per cent. acid 42.2, base 15.6, water 42.2=100.0.

---

* Hence it is kept very dry in close vessels, and used to dry the gases; being for that purpose placed in tubes through which they are made to pass. Impure deliquescent nitre, generally contains this salt.

NITRATE OF MAGNESIA AND AMMONIA.

1. **Preparation.**—Formed by a partial decomposition of nitrate of magnesia by ammonia, or of nitrate of ammonia by magnesia, or better by a mixture of the two nitrates.

2. **Properties.**

(*a.*) *Slender acicular crystals; bitter.*

(*b.*) *Little deliquescent; soluble in* 11 *parts of water at* 60°, *in less at* 212°, and the solution deposits crystals as it cools.*

NITRATE OF ALUMINA.

1. **Preparation.**—The fresh precipitated earth is washed and heated with dilute nitric acid.

2. **Properties.**

(*a.*) *The solution*, which is always acid, *deposits*, after evaporation, *thin crystalline ductile plates.*

(*b.*) *Taste sour and astringent; extremely soluble and deliquescent; decomposed by heat without decomposing the acid.*

(*c.*) *Decomposed by most alkalies and earths.*

3. **Composition.**—*Nitrate of alumina*, when dried between folds of blotting paper, is composed of acid 1 proportion, base 2, water 10, and by a stronger heat it loses a portion of its acid.—*Thomson.*

The nitrates of the other earths are unimportant.

NITRITES.

They cannot be formed synthetically, and the only distinct one is that of potassa.

1. **Preparation.**—*Fuse nitre in a crucible till one proportion of its oxygen has escaped, or partially deflagrate it with charcoal.*

2. **Properties.**—*Deliquescent, and emits red fumes of nitrous acid even with vinegar*, and very strikingly with a strong acid.

It is not certain whether this salt is a nitrite or hypo-nitrite.

RECAPITULATION

Of some principal facts relating to oxygen and nitrogen.

1. *Remark.*—Even a limited acquaintance with chemistry is sufficient to enable us to see that the properties resulting from chemical combination are such as we cannot always foresee, nor account for when known; and that the different results, obtained from combinations of the same elements in different proportions and in various degrees of condensation, are very surprising.

---

* See Thénard, 2d ed. Vol. III, p. 240.

Perhaps the truth of this observation is no where more manifest than with respect to the bodies composed of oxygen and nitrogen. These elements constitute the air that we breathe, and also one of the most powerful of the acids; they give us two other acids scarcely inferior to the other in energy, but possessed of peculiar and characteristic properties; they produce also a gas eminently deadly, and which, by acquiring more oxygen, passes instantly to the condition of one, or of the other of these acids; and finally another gas, deadly to animals that are confined in it, but which, when breathed for a short time, by human beings, is exhilirating beyond any other agent. These differences, which have been fully unfolded in the preceding pages, are attributable solely, so far as we know, to difference of proportion and to different degrees of condensation.

2. Dr. Henry, Gay-Lussac, Dalton, Davy and Thomson, have contributed the most important facts, from which have been deduced the proportions, both by volume and weight, of the compounds of oxygen and nitrogen. Gay-Lussac gave us the law, to which no certain exception has yet been ascertained; "that compounds, whose elements are gaseous, are constituted either of equal volumes of those elements, or that, if one of the elements exceeds the other, the excess is by some simple multiple of its volume."

It is obvious that if gases sustain this relation by volume, they must sustain a similar one by weight, for twice, thrice, &c. the volume must be also twice, thrice, &c. the weight; the temperature and pressure being the same.

3. The following numerical statements exhibit the proportions of oxygen and nitrogen by volume and by weight.

	Measures of		By weight.		By weight for 100 parts.		Equivalent proportions.		Rep. No. of the elements.		Rep. No. of the comp's
	nit.	ox.	nit.	ox.	nit.	ox.	nit.	ox.	nit.	ox.	
Nitrous oxide contains	100	50	100+	57	63.58	36.42	1 +	1	14+	8	22
Nitric oxide,	100	100	100	114	46.68	53.40	1	2	14	16	30
Hypo-nitrous acid,	100	150	100	171	36.81	63.20	1	3	14	24	38
Nitrous acid,	100	200	100	228	30.40	69.60	1	4	14	32	46
Nitric acid,	100	250	100	285	25.97	74.03	1	5	14	40	54

It will be perceived that the smallest number in the first, second, fourth and fifth tables, is a divisor of all the larger numbers in that column, and that those other numbers are of course multiples of the smallest number. Most chemists regard common air as a mixture rather than a compound; but the fact that it corresponds with definite proportions, both in volume and in weight, is perhaps the strongest argument that it is a compound and not a mixture, and perhaps no good reason can be assigned why it should not be added to the acknowledged compounds of oxygen and nitrogen. See p. 197–8.

4. It is thought that all the compounds of nitrogen and oxygen are, essentially, gaseous bodies; the two oxides are certainly so, and can be combined with water in only small proportions. Other combinations have so strong an affinity for water that they have never been entirely separated from it. Nitric acid is of this description, and the two other acids unite very largely with water.

5. In all the combinations of oxygen and nitrogen the elements are in a state of condensation, excepting in the nitric oxide; in this gas, according to the opinion of Gay-Lussac, the oxygen and nitrogen have exactly the same density as in their free state; but in the other compounds the condensation is such that the oxygen gas does not add to the volume; or in other words the contraction is equal to the volume of the oxygen gas.

6. As among gases, the combining proportions correspond with the volumes; the least volume that enters into combination represents the equivalent or smallest combining quantity. In the case of oxygen, however, as already stated, the smallest combining proportion is considered as corresponding with half a volume, as in the composition of water.

7. It is obvious that, as the compounds of oxygen and nitrogen differ from each other only in the proportion of oxygen which they contain, they may be converted into each other by adding or abstracting oxygen. This has been rendered apparent in the statements that have been already given. Nitric acid, by its action on combustibles and metals, is often converted into nitrous acid and nitric or even nitrous oxide; and nitric oxide, by the addition of oxygen, forms the nitrous acids and perhaps the nitric.

SEC. VI.—BORON AND BORACIC ACID.

Remark.—BORON being a substance unknown in common life, it will be most convenient to describe first, the acid from which it is obtained.

BORACIC ACID.

1. NAME AND DISCOVERY.—The composition of this acid being unknown when the nomenclature was formed, it was therefore *named from the Borax of commerce,* its parent substance.

The ancient name of sedative or narcotic salt was given to it by Homberg, a chemist of the Academy of Sciences of Paris, who, in 1702, obtained it by distilling sulphate of iron and borax.

2. NATURAL SOURCES.

(*a.*) *In the saline form, borax,* from which chemists always obtain boracic acid, *is a native alkaline salt,* having soda for its basis. It is brought to Europe from the East Indies, under the name of tincal, and is obtained from Boutan and Thibet; sometimes in small crystalline masses, found two yards under ground; it is procured also from natural lakes, whose waters, containing the salt in solution, yield it it by evaporation, and deposit it in the solid form, at the bottom or in artificial reservoirs. In Europe, the salt goes through refining processes, formerly confined to Holland but now practised in England.

(b.) *In the free state, found in the hot springs of Lipari and Sasso, and in the hot waters of Lake Cherchiago, and Castlenuovo*, in Italy. By evaporating 120 lb. of the water, 3 oz. of the concrete acid are obtained; 12280 grs. of the water of Lake Castlenuovo yielded 120 grains of acid.

Boracic acid is also found *in the vicinity of these lakes, adhering to the rocks in crystals.*

The boracic acid is now obtained in such quantities from Tuscany that it forms an important article of commerce, and is used to form borax by a direct combination with soda.

(c.) *In minerals. Found in the Boracite* of Luneberg, a hard cubical stone, imbedded in gypsum, and containing magnesia as the basis; also in the *Datholite* and in *Tourmalines*, &c.

3. PREPARATION.—*Obtained from borax, both by sublimation and by precipitation.*

(a.) *By sublimation.* A solution of 2 lbs. calcined sulphate of iron, and 2 oz. of borax, is filtered, evaporated to a pellicle, and sublimed in an alembic or retort; the boracic acid, in crystals, lines the upper cavity, and may be swept out with a feather.*

(b.) Or, the acid may be obtained of a beautiful whiteness, *by adding to the borate of soda ½ its weight of sulphuric acid, and subliming.*†

(c.) The usual process is *to dissolve borax 2 parts, in water 6 or 8; and to add 1½ of sulphuric acid diluted with 1 of water*, a gentle heat being continued for a short time; it is set by, and on cooling, crystals of boracic acid, in white shining plates or scales, or minute prisms, will be abundantly precipitated. They must be washed with cold distilled water, to remove any adhering sulphuric acid, or sulphate of soda, and dried on blotting paper. The remaining fluid is a solution of sulphate of soda. The crystals obtained in this manner are still contaminated by a little of the base of the borax, and of the acid used to decompose it. It is said to be obtained purer by using the muriatic or the nitric acid, instead of the sulphuric. Gay-

---

* Chaptal, Vol. I, p. 265.

† The product by sublimation is much less than by precipitation.—*Id.*

Lussac prefers the muriatic, and the boracic acid must be afterwards ignited in a platinum crucible, to expel any excess of the decomposing acid.

4. PROPERTIES.

(*a.*) *The form is that of hexahedral scales, white and brilliant.*

(*b.*) *Feel, a little unctuous, like spermaceti,* which it somewhat resembles. The sublimed boracic acid is much more light and voluminous than the precipitated.

(*c.*) *Taste, cool, bitterish, and slightly sour; inodorous.*

(*d.*) *Reddens blue vegetable colors, effervesces with the alkaline carbonates,* but turns turmeric brown, like the alkalies. Its sp. gr. 1.48—after fusion, 1.803.

(*e.*) "When sulphuric acid is poured upon it, a transient odor of musk is produced."

(*f.*) *This acid a hydrate, for by ignition it loses about* 43 *per cent. which is the water of crystallization;* if heat be suddenly applied, a large quantity of acid rises with the water of crystallization, and in either case we obtain boracic acid, fused, and becoming when cold, a hard transparent glass, not deliquescent, but partly opaque; if dissolved in hot water, it crystallizes again on cooling. Authors are exceedingly at variance as regards the solubility of this acid; but they agree that it is much more soluble *in hot than in cold water, the general statement being* 12 *parts of cold, and* 3 *or* 4 *of boiling water.**

(*g.*) When a saturated solution of this acid, in water, is distilled, a part of the acid passes over, and crystallizes in the receiver; when solid, it will melt into glass, rather than sublime.

(*h.*) *Soluble in* 5 *parts of boiling alcohol, which will then burn with a beautiful green flame;* it is best exhibited by dipping a paper in the solution, and setting it on fire, or by burning it from a watch or wine glass; but sponge does not shew it well, as the yellow color produced by the salt with which it is impregnated, overpowers the green. If the paper which has been dipped in the alcoholic solution be dried first, it then burns with a yellow flame; other substances, which burn with a blue flame, as sulphur, burn green when mixed with boracic acid.†

5. COMPOSITION AND POLARITY.—In the next article, the decomposition of this acid will be mentioned; we may now say that it has a combustible base, called boron, which by union with oxygen, forms boracic acid.

---

* According to Murray it requires 5 parts of boiling water, and 20 of cold; but Davy asserts that it requires 50 parts, even of boiling water.

† Aikin's Dict.

Boron 1 *proportion, represented by the same number as oxygen, namely* 8, +2 *prop. oxygen* 16, *forms dry boracic acid, having* 24 *for its equivalent;* the crystallized acid consists of dry acid 24 + water 2 proportions, 18=42 for the equivalent of the crystallized acid; and for the 100 parts, 42 : 18 : : 100 : 43 nearly, being the quantity of water in the 100 parts, of course there is 57 of dry acid. According to Berzelius, crystallized boracic acid, contains .44 of water, one half of which is expelled at a heat above 212°, and the other half when it combines with bases, but it cannot all be expelled by heat alone.

6. POLARITY.—In the galvanic circuit, this acid goes to the positive pole, and is therefore, *electro negative.*

7. USES.—It melts very easily, *and by acting as a flux, it favors the fusion of minerals,* with the blow pipe. *It is used in the analysis of stones,* aiding their fusion in the crucible. After it is melted by itself, it endures *a white heat without volatilization,* and as it cools into a glass, *it is called a glacial acid, being one of three that bear that name, viz. the phosphoric, the arsenical, and the boracic.*

In the dry way, viz. with heat, *the boracic acid displaces all the acids except the phosphoric;* this arises from its great fixity and fusibility by which it is able to vitrify the bases of the salts, even of the earthy salts.

BORON.

DECOMPOSITION OF BORACIC ACID.

1. DISCOVERY OF BORON.

(*a.*) The power of 500 pairs of galvanic plates extricates from moistened boracic acid *a peculiar olive colored combustible basis, first ascertained by Davy, in* 1807.

2. PROCESS.

(*a.*) *Better obtained by heating very pure vitreous boracic acid along with potassium,* in tubes of green glass or copper, iron or brass; preferably the last.

(*b.*) 12 *or* 14 *grains of each substance were employed;* but 8 grains of boracic acid will saturate 20 grains of potassium. At 302° Fahr. ignition comes on, a little hydrogen appears, the potassium is converted into potassa,* and boron is obtained.

---

* See Recherches Physico-Chimiques, Vol. I. Berzelius employs the fluo-borate of potassa with potassium in a crucible; the boron is to be washed with sal-ammoniac, and lastly with alcohol; as water carries some of it through the filter. This process is said to be less expensive in potassium than the other.

3. PROPERTIES.

(*a.*) *An opake, pulverulent, olive colored mass,* does not scratch glass, *does not conduct electricity,* is tasteless, inodorous, insoluble in water, ether, alcohol and oils, and does not affect blue colors.

(*b.*) *Burns in atmospheric air, at a heat below* that of boiling olive oil, or at about 600°, with a red light, sparkles like charcoal, *and produces boracic acid,* the coating of which, on the boron, soon stops the combustion.

(*c.*) *Not fused or volatilized by a white heat,* in close vessels, *but* becomes dense enough to *sink in sulphuric acid* of the sp. gr. 1.844, hence its sp. gr. must be nearly 2.

(*d.*) *The heat of a spirit lamp makes it burn brilliantly* in oxygen gas, and boracic acid sublimes.*

(*e.*) *It burns spontaneously in chlorine gas,* and forms a new gas, which when brought into contact with atmospheric air, smokes as much as fluoboric gas. Freed from excess of chlorine, by standing over mercury it becomes colorless, and is rapidly absorbed by water; its composition is chlorine, 90.743, boron, 9.257=100.—*Berzelius.*

(*f.*) *Nitric acid converts it into boracic acid,* while nitric oxide gas is liberated.

(*g.*) *It dissolves in hot sulphuric acid with effervescence,* and potash throws down a black precipitate.

(*h.*) Muriatic acid acquires a green color, but its action is feeble, and there is no solution.

(*i.*) *With fixed alkalies, it forms pale olive-colored compounds,* from which muriatic acid throws down dark precipitates.

(*j.*) *Sulphur dissolves it by long fusion, and acquires an olive tint* —little action with phosphorus, none with mercury.

(*k.*) *It burns vividly, when mixed with chlorate or nitrate of potash,* and thrown into a red hot crucible.

(*l.*) *Boron heated in the vapor of sulphur, unites with it, with the appearance of combustion*—producing a sulphuret, which is white and opake, and which, when thrown into water, gives off sulphuretted hydrogen and forms boracic acid.

4. EQUIVALENT NUMBER AND POLARITY.

The equivalent of boron is 8, as already stated. In the galvanic circuit, it goes to the negative pole.

5. NATIVE BORON.

Boron is to be regarded as a peculiar combustible; a little resembling carbon in fixity in the fire, but it is unlike it in being a non-conductor of electricity.

---

* There is a black residuum which produces more boracic acid by being heated again in oxygen gas.

BORATES OF ALKALIES AND EARTHS.

General properties.

1. In the humid way, decomposed by all acids except the carbonic.

2. In the dry way, the action is often reversed, especially where the acid of the other body has a tendency to become gaseous.

3. Boracic acid attracts the earths more forcibly than the alkalies.

4. Alkaline borates are very soluble in water; the earthy the reverse.

5. The boracic acid being feeble, it neutralizes the alkaline bases imperfectly, and hence the borates of the alkalies have alkaline characters.

6. Borates are very fusible.

7. Digested with strong sulphuric acid, the residue imparts to alcohol the power of burning with a green flame.

BORATE OF POTASSA.

1. PROCESS.

(*a.*) Boil boracic acid in caustic potash, either to saturation or so as to leave a slight excess of alkali.

(*b.*) In the latter case, *it crystallizes in pretty large four sided prisms*—taste sub-alkaline.

2. PROPERTIES.

(*a.*) *Not altered by the air*—by heat, swells, foams, and runs into a clear glass.

(*b.*) Decomposed by lime, baryta, and magnesia.

BORAX.

BI-BORATE OF SODA, *formerly called sub-borate.*

1. PREPARATION.—*It can be formed synthetically*, but this is unnecessary, as it is abundant in commerce.

2. PROPERTIES.

(*a.*) *Turns vegetable blues green;* taste, cool, sweetish, and subalkaline.

(*b.*) *Soluble in* 12* *parts of cold water, and in* 6 *of boiling;* slightly efflorescent; deposits crystals by cooling; prisms with 6 irregular sides. Phosphoresces by collision of its crystals.

(*c.*) *Suffers the aqueous fusion*, is very much inflated, and at ignition *becomes a pellucid glass;* soluble again in water.†

---

* Henry says 20.

† Provided it were melted in a silver crucible or *hastily* in one of earth, for it is prone to corrode earthen crucibles.

(*d.*) *Sp. gr.* 1.74—after fusion, flies and cracks to pieces in cooling.

(*e.*) Action of the acids as already mentioned under boracic acid, and the general characters of the borates.

(*f.*) *If only the excess of soda be neutralized* by an acid, *the whole*, by evaporation *becomes a confusedly crystallized mass*, containing all the ingredients.

(*g.*) *The excess of alkali can also be saturated by boracic acid;* the salt takes up nearly half its weight, and ceases to affect the blue colors, to effloresce, to taste alkaline, and to crystallize in the same form as borax.

(*h.*) *Baryta, strontia, lime, and magnesia, decompose borax.*

(*i.*) *Potash also* decomposes it, but there is no precipitate, because soda dissolves borate of potash.

(*j.*) *Borax fluxes silica into a transparent, and alumina into an opake glass;* the ingredients being in equal proportions, the compound is insoluble in the mineral acids, but a great excess of borax makes it soluble.

(*k.*) *The borax of the shops exhibits an imperfect crystallization*, with a figure approaching to the hexahedral prism. The crystals are slightly efflorescent.

3. Composition and representative number.

Gmelin, acid, 35.60, base, 17.80, water, 46.6=100 } nearly.
Thomson, 31.51, 20.42, 48.0=100 }

The representative number of boracic acid has already been stated as being 24. According to Dr. Thomson, this salt is composed of

2 proportions of boracic acid, - - =48
1 " soda, - - - - =32
8 " water, - - - =72

Its equivalent, 152

In the 100 parts, acid 31.58, soda 21.05, water 47.37.

4. Miscellaneous.—The natural and commercial history of this salt has been already given under boracic acid. In addition to the localities already named, it is found in China, in Peru, in Transylvania and Saxony.*

The crude borax brought from the East Indies and the Levant, is always enveloped in an oleaginous matter; which Vauquelin found to be a soap with soda for its base. It is believed that the natives cover it with a film of oil to prevent its efflorescence, and it is said to be moistened by sour milk for the same purpose.

It is purified by repeated solutions and crystallizations, in vessels of lead; they obtain from the tincal .80 of borax, and they expose it to heat as a preparatory operation, to burn off the oily or fatty matter which surrounds it. Formerly the manufacture was confined to Holland, and it seems not to have been known that an addition of soda was necessary to saturate the boracic acid.

---

* Thénard, III, 90.

Borax is now abundantly manufactured in France, by the combination of the boracic acid, obtained from Tuscany, with soda; the French consume, annually, about 25 tons, and they no longer import the tincal.

In forming borax in France, they dissolve 1200 lbs. of carbonate of soda in 1000 lbs. of water, and add, by 20 lbs. at a time, 600 lbs. of Tuscan boracic acid; the processes are conducted in leaden boilers, by repeated solutions and crystallizations, and many circumstances must be attended to in order to obtain large and handsome crystals. 100 lbs. of the best Tuscan boracic acid, containing about half its weight of the pure acid, produce about 150 of refined borax; but as the acid is not always pure and there is some loss in the processes, the product is ordinarily not more than 140 or 142 lbs. of borax from 100 of boracic acid.*

5. Uses.—Formerly used internally as a *sedative*, and still employed to form a gargle to remove the aphthous crust from the mouths of children; it is a flux for the blowpipe; for the vitreous materials of artificial gems or pastes, and for the glazing of porcelain. Known from remote antiquity, and it is mentioned by Pliny as *chrysocolla* or *gold glue*, in allusion to its use in soldering the precious metals; from which it removes impurities, preventing also oxidation.

BORATE OF AMMONIA.

1. Process.—By digesting boracic acid with ammonia, we obtain small rhomboidal octahedra.

2. Properties.

(*a.*) *Taste sharp; turns the blue vegetable test liquors green;* undergo slight efflorescence in the air.

(*b.*) The ammonia is expelled by heat and the boracic acid is left; according to Lassone,† the entire salt melts into a grayish glass, and gives after solution, the same crystals as before.

(*c.*) Decomposed by the fixed alkalies both in the moist and dry way.

BORATE OF BARYTA.

Add boracic acid to barytic water, and a white, insipid, insoluble powder precipitates.

BORATE OF STRONTIA.

1. Same mode of formation; a copious precipitate.

2. Prone to an excess of base; soluble in 130 parts of boiling water, and is scarcely affected by cold water.

---

* Gray's Op. Chem. p. 526.

† Aikin, Vol. I, p. 156.

BORATE OF LIME.

1. Process.—*Mix boracic acid* or borax *with lime water*, or any soluble salt of lime.

2. Properties.

(*a.*) *A white, insoluble, insipid powder;* fusible at ignition.

(*b.*) Chalk 2, and boracic acid 1, at ignition, produce a yellow glass so hard as to strike fire; with the reverse proportions, the matter often runs through the crucible.

BORATE OF MAGNESIA.

1. Process.—*By long digestion of boracic acid with magnesia; or a mixture of any soluble borate with any soluble magnesian salt,* produces this combination.

2. Properties.—*An insoluble and insipid precipitate,* without any crystalline form; fusible, at ignition, into a white semi-transparent glass.

The bi-borate of magnesia is found native at Luneberg, Germany, under the name of the boracite; it is in small cubical crystals, often highly modified.

BORATE OF ALUMINA.

1. Newly precipitated and undried alumina is digested with boracic acid.

2. Evaporation gives a viscid mass, through which minute crystals are interspersed; taste astringent.

Sec. VII.—Fluoric Acid.

Remark.—In order to entitle the fluoric acid to a place here, strict method would require that a combustible basis should have been proved to exist in this acid, and that this base should be described in connexion with the acid. But as we have no decisive proof as to the nature of the fluoric radical, the present arrangement can be considered as provisional only; for it remains yet to be seen whether fluoric acid is composed of a combustible basis and oxygen, or of a peculiar principle, analogous to iodine and chlorine, and hydrogen, or whether it has a composition entirely peculiar; for all analogy leads to the opinion that it is compound.

1. History.—*Re-discovered by Scheele, A. D.* 1771;* for it appears to have been first obtained (A. D. 1670,) by the artist Shankhard, at Nuremburg; and also by Pauli, at Dresden, A. D. 1725, who employed it, as Shankhard had done, to corrode glass, but

---

* Vide Scheele's Essays, Vol. I.

the subject was forgotten, till Mr. Scheele revived it. The acid of Scheele was, however, impure, and it was not till Gay-Lussac and Thénard obtained it,[*] that it was known in purity.

2. ORIGIN AND NAME.—*Exists abundantly in the beautiful mineral called* Derbyshire spar; it being found in great quantities in that county, in England. This mineral is called also fluor, or fluor spar, because, being fusible, it is used as a flux for ores. It is usually crystallized in cubes, with an octahedral nucleus, which gives, by continued dissection, octahedra and tetrahedra. When pure, it is white, but it is most commonly colored.

As the fluor spar affords the acid in question, the name, fluoric acid, was bestowed, because the composition was then, as it is still, unknown.

3. PREPARATION.

(*a.*) Gay-Lussac and Thénard employed a leaden cylinder, *connected by a recurved leaden tube, with another leaden vessel for a receiver;* the latter was kept cold by ice.

(*b.*) Finding lead so liable to fusion, I have used a silver alembic, with a capacity of 16 fluid ounces, its head and tube 2½, *and the tube fitted tight to a silver bottle* of 3½ oz. the latter furnished with a *ground silver stopper*, to preserve the acid, and to save the necessity of pouring it into another vessel.

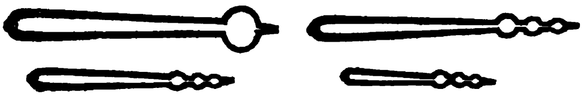
(*c.*) *In the alembic are placed 2 oz. of pure fluor spar, and 4 oz. of strong sulphuric acid; the receiver is surrounded by ice or snow, and a few live coals are placed beneath the alembic, whose head is made securely tight by a lute of finely powdered pipe clay, placed in the joint, and a rag, smeared with the same,* is bound tightly over it. The receiver should not be pressed hard home, so as to be accurately tight upon the tube, but a little room should be left for the escape of the vapor of the acid.

(*d.*) *The apparatus should be under a well drawing flue, the hands protected by thick gloves, and the receiver, when moved, should be grasped by small tongs*, furnished with curvatures, to fit the neck of the bottle.[†] In about half an hour, the process will be through, and

---

[*] Recher. Phy.-Chim. Vol. II.

[†] As represented in the annexed figures, which being made with corresponding flexions, and of various sizes, from those that are very delicate and adapted to sustain the minutest flasks by the neck, to such as will lift a heavy crucible, or a basin, are highly convenient.



on shaking the bottle, the movement of the liquid fluoric acid will be distinctly perceived.*

4. Properties.

(*a.*) *An exceedingly volatile fluid; extremely corrosive, suffocating, and dangerous.*

(*b.*) *At 32° Fahr. it is a colorless fluid.* Sp. gr. 1.0609, and by gradual additions of water, its density is increased to 1.25.†

(*c.*) *Retains its liquid form at* 60°, *if preserved in well stopped silver bottles:*‡ those of lead answer but imperfectly, as the acid corrodes them and escapes.

(*d.*) *Does not congeal at* —4° *Fahr.*

(*e.*) *When strong, emits into the air dense white fumes,* which evidently arise from a combination with the watery vapor.

(*f.*) *Potassium burns, or rather detonates in the liquid fluoric acid;* hydrogen gas is disengaged, and a solid white substance is formed. This experiment must be performed in a metallic vessel; a platinum crucible or capsule answers well.

(*g.*) *Dropped into water, it hisses like a hot iron,* and there is great agitation, and even ebullition, especially when water is added to the acid.

---

* See Am. Jour. Vol. XVI, p. 354.

With the proportion of acid mentioned in the text, (that of Gay-Lussac and Thénard,) the silver alembic is sometimes attacked, and corroded through and through, as I have more than once experienced. If we diminish the quantity of acid, using 3 to 2 of fluor, or even equal weights, the danger to the vessel is much diminished, but the product of fluoric acid is less, and the residuum in the alembic is much more difficult to remove. To a certain extent, the smaller the proportion of sulphuric acid used, the stronger and more fuming is the fluoric acid obtained. A similar effect is produced by previously heating the sulphuric acid, for some time, near to its boiling point. The reason is obvious; it is the water of the sulphuric acid that serves to condense the fluoric acid, otherwise incoercible, at least at the temperature of ice, and under the ordinary pressure, and therefore, the less in quantity, and the stronger the sulphuric acid, (provided it is sufficient for the decomposition,) the more concentrated will be the fluoric acid. I have known the latter so active as to be of very difficult condensation; blowing out the silver ground stopper with violent puffs, and rapidly wasting away by its own evaporation. A little water in the receiver, however, prevents this, and if our object is to etch on glass, a diluted acid is much preferable. The strong acid of Gay-Lussac is needed only to display its own dangerous and wonderful energy, and too much caution cannot be recommended to those who prepare it.

† This is said to be unlike other fluids, but is it however, really an exception? Alcohol and water, and sulphuric acid and water, acquire by union, a gravity greater than the mean. This acid appears to attract water with more energy than the sulphuric, much more heat is evolved by the condensation, and the density ought to be increased considerably.

‡ *In silver bottles, with well ground stoppers, in a cellar, it can be kept the year round;* but from lead bottles, however well ground and luted, it almost always makes its escape, corroding the lead; and glass vessels in the vicinity are extensively covered with a white deposit of silica, rendering them opake. This eeffct mentioned by Dr. Thomson, (First Principles, Vol. II, p. 165.) I have often seen.

(*h.*) ***Respiration. The vapor is extremely dangerous in the lungs;*** and should be anxiously avoided.

(*i.*) *Contact with the body. This also is dangerous; excepting prussic acid, there is perhaps no agent so deleterious.* It instantly disorganises the skin; painful and obstinate ulcers are formed, for it seems to penetrate into the very tissue of the parts; there is a general irritation of the system, and sometimes extirpation of the injured portion is the only remedy. *Even contact with the vapors floating about should be avoided,* for they immediately irritate the skin, and may produce permanent injury. ‡

(*j.*) Fluoric acid, largely diluted in vessels of lead, platinum or silver, has a decidedly acid taste, and reddens the vegetable blues.

(*k.*) It forms salts with the salifiable bases; "and with acids weaker than itself, it produces compounds, in which the latter serve as a kind of base." By dilution with water, these acids suffer a partial decomposition, and deposit a portion of their base; of this description are fluo-boric, and fluo-silicic acids, which will be described in their places.

(*l.*) The constitution and combining weight of fluoric acid will be mentioned at the conclusion of the whole subject.

FLUO-SILICIC ACID GAS.

The action of fluoric acid upon silica is so peculiar, as to merit a distinct consideration.

The strong acid of Gay-Lussac instantly soils glass; attacking it with as much energy as sulphuric acid does an alkali; heat is evolved, *and instead of having its volatility diminished, it becomes, by this union, permanently aëriform; a true gas;* although before only a vapor.

1. PREPARATION.

(*a.*) *This gas is of course produced, whenever the ordinary process for fluoric acid is performed in glass vessels,* but it is usual to *add half as much pulverized glass as fluor spar to the mixture of equal parts of the latter, and strong sulphuric acid.*

(*b.*) In the latter case, *the glass retort* will be much less corroded, but in my experiments it has always been attacked in some degree,

---

‡ Gay-Lussac and Thénard mention (Recher.-Phys. Chim. Tom. II, p. 11,) that some of their assistants suffered severely for a month, from exposure for a few minutes to the acid vapor, coming in contact with the fore finger and thumb; and a dog upon whose back, deprived of hair at that place, six drops of this acid were allowed to fall, suffered extremely, and in a few hours died in agony. They state that the effect is not always perceived till 7 or 8 hours after the contact of the vapor, and that even when it is too feeble to be observed, it produces in a few hours, acute pain, loss of sleep, and fever. Similar results have several times been observed in my laboratory.

and if not protected by the mixture of glass, it is usually eaten through and through.

(*c.*) Even with the addition of glass, I have never failed to find the vessels covered by an opake white crust of silica,* less remarkable however than when the fluor and sulphuric acid alone are mingled.

2. **Properties.**

(*a.*) Received *over mercury, it is a gas, colorless and invisible; it extinguishes a burning candle*, but shows a blue border surrounding the red flame; it *smokes in the air*, producing a dense fog like muriatic acid gas, which, in odor, it strongly resembles; *the cloud is produced by the combination of the acid gas with the atmospheric water, silica being at the same time deposited*, in a state of minute division.

(*b.*) *It is fatal to animals confined in it, and is suffocating to the experimenter*; but its properties are so repressed by combination with the silica, that it is not particularly dangerous to inhale a little of it mixed with the air of the room.

(*c.*) *Sp. gr.* 3.6111, *air being* 1, and 100 cubic inches at 60° Fahr. and 30 inches barometer, weigh 110.138 grains.—*Thomson.*

(*d.*) Dr. John Davy, by decomposing it by liquid ammonia, found that 61.4 *of the weight of the gas is silica.* Dr. Thomson, from 40 cubic inches of the gas (=44.05 grains,) obtained 27.14 silica, which is at the rate of 61.60 per cent. *It is indeed most singular, that a very volatile vapor, by corroding siliceous bodies and becoming charged with more than* 60 *per cent. of a naturally very fixed and almost unalterable earth, should become a gas, which, when dry, is permanent.*

(*e.*) *Water. This fluid absorbs about* 263 *times its volume of this gas, and the solution does not corrode glass vessels.* During the solution, one third of the silica is deposited, and the remainder with the fluoric acid is retained in the water, and was called by Dr. Davy, *sub-silicated fluoric acid. It is sour and reddens litmus.*

(*f.*) *The precipitate is a gelatinous hydrate of silica*, and after being washed and ignited, it is regarded by Berzelius as pure. It affords perhaps the easiest method of obtaining that earth.

(*g.*) *Silicated fluoric acid gas*, when passing into the receiver, *often becomes cloudy from the precipitation of the silica by the moisture of the air.*

(*h.*) *If distilled into a receiver containing water, it becomes covered with a siliceous crust*, which eventually covers the water, and then the condensation ceases; but if the receiver be shaken, the crust will break and fall, and the condensation will go on again.

---

* This may be presented by covering them with a coat of bees wax, or probably copal varnish, but this last I have not tried. It is said, however, that dry glass is not attacked by *silicated fluoric acid gas.*

(*i.*) *If the gas be let up through water standing over mercury, the silica is deposited in the form of vertical tubes.*

(*j.*) *When moist substances are placed in an atmosphere of silicated fluoric acid gas, they become encrusted with it,* so as to resemble petrifactions; moistened sponge, frogs, lizards, &c. may be enveloped in this manner, and covered with a siliceous coat.

(*k.*) *Silicated fluoric acid gas condenses ammoniacal gas; 1 vol. of the former to 2 of the latter;* and it would seem that the combination takes place in no other proportion; *the product is a dry white acidulous salt,* from which water precipitates silica, and if the solution be boiled in glass vessels, they are corroded with energy.—*Henry.*

(*l.*) *By combining the silicated fluoric acid gas with liquid ammonia, a pure fluate of ammonia is obtained,* while the silica is all precipitated. This fluate of ammonia may then be decomposed by sulphuric acid, and fluoric acid obtained free from silica.

(*m.*) *This gas unites with other bases, and forms compounds* that have been called, as Berzelius thinks improperly, fluo-silicates.*

3. Etching upon glass.

(*a.*) In consequence of the energy with which fluoric acid acts upon glass, *it is necessary only to protect it where we would not choose to have it corroded, and to expose it in those places where we would wish an indelible trace.*

(*b.*) *Bees wax† forms a good protection, but one still better is made of this substance and turpentine melted together and spread over the warm glass, until an even coating is obtained;* a rim or border of the same substance is made to surround the glass, and then *the pure fluid acid, diluted to such a degree that it does not smoke, may be poured on,* and the glass should be carefully turned till the whole is thoroughly moistened. *Two or three minutes are* ordinarily *sufficient* to complete the etching, and *the same* portion of *acid will etch a number of plates successively.*‡

(*c.*) Those who have not a proper distilling apparatus may effect the same object, but much more tardily and imperfectly, by allowing the vapor of the fluoric acid, as it rises from an open vessel of tin or lead to strike the glass plate, but there is danger of corroding it on the wrong side, unless that too is protected; and also of melting and disfiguring the varnish by the contact of the hot acid.

---

* See his memoir, Ann. de Chim. et de Phys. Tom. XXVII, and Ann. of Philos. N. S. quoted by Henry.

† Isinglass is also mentioned by Mr. Murray, as a protection, but this I have never tried.

‡ Am. Jour. Vol. VI, p. 355. I find this process easy and always successful; an engraver prepares the plates, and the etching is done in the laboratory.

(*d.*) *Diamonds and various gems have been exposed to the action of fluoric acid, but without much effect.*[*]

FLUO-BORIC ACID GAS.

1. History.—This singular compound was *obtained about the same time by Gay-Lussac and Thénard and by Sir H. Davy*, although the former gentlemen first published their observations. Both had the same object in view, that of obtaining fluoric acid gas free from water.

2. Process.

(*a.*) *A coated iron tube; vitreous boracic acid* 1 *part and fluor spar* 2, *with heat.*

(*b.*) An easier way is to *distil, in a glass retort,* 1 *part vitreous boracic acid,* 2 *fluor spar and* 12 *strong sulphuric acid.*[†] Common crystallized boracic acid answers perfectly well.[‡]

3. Properties.

(*a.*) *Colorless and transparent, and, over mercury, permanently aëriform.* It reddens litmus.

(*b.*) *Sp. gr.* 2.36; at 60° Fahr. and 30 in. bar. 100 *cubic inches* of this gas *weigh* 72.044 *grains.*[§]

(*c.*) *Extinguishes flame and life;* very pungent and suffocating, but less so than fluo-silicic acid gas.

(*d.*) *The bubbles of this gas break, in a moist air, in dense white fumes almost like snow.*

(*e.*) *This arises from the strong attraction of the gas for water,* which it detects in almost every other gas and precipitates in a cloud, to the density of which the boracic acid, as well as the moisture, probably contributes.

(*f.*) *Water absorbs* 700 *volumes of this gas and acquires the sp. gr.* 1.77; although it increases in volume. *The acid* thus formed *is dense, fuming and highly corrosive,* and considerably resembles sulphuric acid. It requires a heat above 212° to make it boil, and it condenses again in striæ; *it chars animal and vegetable substances like the sulphuric acid;* it blackens paper, and forms a true ether with alcohol. On glass it has no effect, its affinity for silica being evidently supplanted by that of the boracic acid.

---

[*] Other stones were also tried. The agate lost its transparency and color; the avanturine its brilliant particles, and appeared like a gray pebble; the bloodstone became soft and brittle, and its beautiful colors were changed and became dull; garnets were corroded, and assumed a dark red color, and the gypsum of Montmartre and the sandstone of Fontainbleau were dissolved. Rock crystal is not attacked so readily as glass, owing to its stronger aggregation. (Gray's Op. Chem. p. 457.) The minerals generally lost weight, and the effects may be referred either to the affinity of the fluoric acid for silica or for the other constituents of the stones. Fluoric acid is useful in giving indelible labels upon glass for the laboratory; and attempts have been made, on the score of economy, to substitute glass plates, corroded by fluoric acid, instead of copper plates, and a funeral piece in honor of Scheele was executed in that way; but it is difficult to sustain the glass and prevent it from cracking in the press.

[†] J. Davy, Phil. Trans. 1812.

[‡] The previous vitrification adds considerably to the trouble of the experiment, and for a class experiment presents no important advantage.

[§] Thomson, First Prin. Vol. II, p. 179.

(*g.*) *It unites with ammoniacal gas in 3 proportions;* in equal measures, if the ammonia be first introduced into the tube; the compound is then solid and neutral; if the fluo-boric gas pass in by bubbles, the combination is liquid, and in the proportion of 2 ammonia to 1 of the acid gas. If to this last more fluo-boric gas be admitted, it is absorbed and the product still remains liquid. Heat expels part of the ammonia from both the fluid compounds, and a solid, volatile and unaltered by heat, is obtained.*

Nature of the fluoric principles.

1. Remark.—*Three acids, the boracic, the fluoric and the muriatic, were, for many years, mentioned in connexion, as undecomposed bodies. The boracic,* as we have seen, *has been satisfactorily decomposed,* and the analysis has been confirmed by synthesis. Its constitution is in perfect accordance with that of most of the other acids, as it consists of a combustible base and oxygen. *The muriatic acid,* as we shall soon see, *is now regarded,* by the chemical world, *as a compound of* an inflammable basis, namely, *hydrogen,* not however with oxygen, but *with chlorine,* which is admitted as a principle analogous to oxygen, fluoric remains for

2. Composition of fluoric acid.—In the researches of Sir H. Davy, of Gay-Lussac and Thénard, and of Berzelius, may be found most of the facts relating to this investigation. It would occupy too much room to recite them here in detail.† Potassium and sodium can both be made to burn vividly in fluo-boric and fluo-silicic acid gas, and a combustible substance makes its appearance, but it is evidently the basis of the boracic acid in the first case and of silica in the second; and accordingly, when they are, respectively, made to burn in oxygen gas, boracic acid and silica are reproduced. Those experiments may therefore be regarded as affording a convenient method of decomposing boracic acid and silica; and in that view they are valuble, and the method by fluo-silicic gas or the fluo-silicate of soda and potassa is the most valuable one which we possess for obtaining the basis of silica. (See p. 277.) Potassium, as already stated, burns vividly, and even with explosion, in the strongest liquid fluoric acid that has hitherto been obtained. As that fluid is always

---

* Henry, Vol. I, p. 366.

† See Recherches Physico-Chimiques, Tom. II, Phil. Trans. for 1813 and 1814, and the scientific journals of the day.

procured by the aid of sulphuric acid,* there would seem to be no reason to doubt that it must contain water,† the decomposition of which, according to the opinion of Gay-Lussac and Thénard, affords the hydrogen which is evolved and supplies oxygen to the potassium, by which it becomes potassa and unites with fluoric acid to form an acid fluate of potassa. In this experiment, therefore, there seems no reason to admit that the fluoric acid is decomposed, and it would be premature to say that it consists of oxygen and a combustible basis, although such a constitution is certainly both very possible and very probable.

On the whole, we must, for the present, and until additional researches shall clear up the difficulty, rank fluoric acid among the undecomposed bodies;‡ although from analogy, I have placed it with bodies known to be compound.

EQUIVALENT OF FLUORIC ACID.

Dr. Thomson,§ has concluded that the representative number of fluoric acid is 10, and Berzelius has formed the same conclusion; this is upon the supposition that the fluates are compounds of fluoric acid, and an oxidated combustible or metallic base; if therefore the fluoric acid contains one proportion of oxygen 8, the base will be expressed by 2.*

---

* It would seem that the fluoric acid exists anhydrous in fluo-silicic and fluo-boric gas, and in its own saline compounds, fluor spar, &c. but that it cannot be separated, *in its pure state*, from its combinations, except by the aid of an acid that contains water.

† Especially if the sulphate of lime remaining in the distilling vessel be, as it doubtless is, *anhydrous;* for besides the strong affinity of the fluoric acid for water, the residuum in the vessel is usually heated to a degree that expels all water from the natural hydrous sulphates of lime, and I have found it very hard to detach.

‡ Deference to the opinions of very able men, and to the practice of some of the most respectable chemical authors, would have led me to place the hypothetical principle *fluorine*, in the text and in the tabular arrangement. But it appears plain that fluorine would never have been thought of, but for the supposed analogies with chlorine, which controverted topic was keenly agitated about the time of the principal modern researches upon fluoric acid, and the extension of these analogies, by the discovery of iodine, almost at the same period, seemed to make it, in a sense, necessary to admit the existence of a similar principle in fluoric acid. These analogies may be mentioned again, after we have gone through with the history of chlorine and iodine. For the present, however, it may be remarked that there is no *decisive experiment*, proving the *existence* of fluorine.

When Sir H. Davy galvanized the strongest liquid fluoric acid, an inflammable gas, doubtless hydrogen, was disengaged at the negative pole, and the platinum wire was rapidly corroded at the positive; while a chocolate colored powder collected on the wire. As it does not appear to have been examined, we are in no condition to decide whether it was, as imagined, a compound of fluorine with platinum, or an oxide of that metal. We do not know whether the solvent powers of the fluoric acid, great as they are, may not have been so exalted by the galvanic energy, that this agent may have become capable, in its acid character, of attacking even platinum, while it would be even possible that the oxygen requisite to oxidize the metal may have been derived from the water which would then give out the hydrogen, its other element at the negative pole.

To me it appears premature, to place fluorine, a principle purely hypothetical, along side with chlorine and iodine, whose distinct existence and peculiar energy are manifested in so many remarkable forms.

§ First Prin. Vol. II.

EQUIVALENT OF FLUO-SILICIC ACID.

Reasoning upon the per centage of silica in fluoric acid gas, (61.4 John Davy,) its constitution is inferred to be,

1 proportion of fluoric acid,	-	=10
1 " silica,	- -	16
		26, which would appear to be its equivalent number.†

EQUIVALENT OF FLUO-BORIC ACID.

Upon the same authority, it is stated at

1 proportion fluoric acid,	- - -	10
1 " boracic acid,	- - -	24
		34

FLUATES.

General characters.

Upon the supposition that they are compounds of fluoric acid and oxidated bases, rather than of fluorine and bases, or that they are fluates and not fluorides.

1. *Formed synthetically*, by the union of pure fluoric acid with the base, *or by double exchange* of a solution of an alkaline fluate with the intended base combined with some acid in a soluble form.
2. *The neutral fluates with fixed bases, fusible at high temperatures*, and in close vessels; if dry, not decomposed by any degree of heat.
3. *Fluates of alkalies and alkaline earths not decomposed by heat*, even when aided by the affinity of combustibles.
4. *No anhydrous acid except the vitreous boracic decomposes them by heat alone*, and this only by combining at the moment of decomposition with the fluoric acid.
5. *Decomposed by* being moderately heated with *sulphuric, muriatic, phosphoric and arsenic acids.*

---

* If the fluates are regarded as fluorides, that is, compounds of fluorine with a metal or combustible, then its equivalent is obtained by adding to that of fluoric acid the weight of one proportion of oxygen supposed to exist in the metallic base; upon the supposition that the salts are fluates, this will give 10+8=18, for the number representing fluorine.

† Thomson's First Prin. Vol. II, p. 176.

6. *The vapor*, which rises, *corrodes glass;* this effect is decisive as to the presence of fluoric acid.

7. *Alkaline fluates deliquescent and difficult to crystallize.*

8. *There are five native fluates*, namely—

(*a.*) Fluor-spar or fluate of lime—the most important.

(*b.*) The double fluate of soda and alumina, called the cryolite.

(*c.*) The fluate of cerium.

(*d.*) The double fluate of cerium and yttria, and what some choose to call—

(*e.*) The fluo-silicate of alumina—the topaz.—*Turner.*

FLUATE AND BI-FLUATE OF POTASSA.

1. PREPARATION.—FLUATE.

(*a.*) *Caustic potash and fluor spar do not produce this compound by heat, but carbonate of potash and fluor do by double exchange.*

(*b.*) *Water being added*, the carbonate of lime is precipitated, and *the fluate of potassa is dissolved.*

(*c.*) *Formed by saturating pure liquid fluoric acid with potassa,** much heat is disengaged.

2. PROPERTIES.

(*a.*) *A gelatinous deliquescent mass*, difficult to crystallize—assumes a foliated form if evaporation is pushed to dryness.

(*b.*) *Suffers the aqueous, and afterwards the igneous fusion*, by heat.

(*c.*) *Fluate of potassa acts upon silica and glass*, especially when aided by heat, and even spontaneously in the course of a day or two, and a triple compound is formed of earth, acid, and alkali.

(*d.*) *The sulphuric acid expels the fluoric with brisk effervescence.*

BI-FLUATE.

1. FORMATION AND PROPERTIES.—This salt is *readily formed by leaving the acid in excess*, and is easily converted into the neutral fluate by heating it to redness, which expels one proportion of fluoric acid. The bi-fluate crystallizes in square tables with the edges replaced; it is very soluble in water.

2. COMPOSITION.—1 *proportion neutral fluate, and* 1 *of fluoric acid;* by ignition, it leaves 74.9 of neutral fluate, and the remainder is composed of 11.5 of water, 13.6 acid.†

---

* Or its carbonate.

† Berzelius, Ann. de Chim. et de Phys. Tom. XXVII.

Addition to fluate of potassa.—It is common in laboratories, to pass silicated fluoric acid gas through water; gelatinous silica is deposited, containing fluoric acid, and an acid fluate of silica remains in the water. If to this fluid, caustic potash, or its carbonate, be added, there is formed an acid fluate of silica and potassa soluble

FLUATE OF SODA.

1. **Preparation.**

(*a.*) *In the same manner as the preceding*, and also by decomposing the acid fluate of silica by soda.*

(*b.*) Dr. Thomson formed it† by passing fluo-silicic gas, to saturation, through solution of carbonate of ammonia, which was then decomposed by carbonate of soda, added by little and little; after evaporation to dryness in a silver vessel, resolution and filtration to get rid of a little silica, it was again evaporated and crystallized. The crystals are small and crackle between the teeth.

2. **Properties.**

(*a.*) *In transparent crusts like ice;* after the expulsion of the water of crystallization forms opaque white crusts, becoming again transparent by immersion in water.

(*b.*) *Not deliquescent or efflorescent;* a little more soluble in hot than in cold water; *effervesces vigorously with sulphuric acid; taste bitter and styptic;* but not so strong as the fluate of potassa; suffers the aqueous fusion.

FLUATE OF AMMONIA.‡

1. **Preparation.**

(*a.*) *Pulverized fluor* 1 part and sulphate of ammonia 2; heat them in a subliming apparatus; ammoniacal gas is liberated at first, and then fluate of ammonia sublimes and incrusts the capital.

---

in 6 or 7 hundred parts of water; the filtered fluid, on evaporation, gives a fluate of silica and potassa, gelatinous, very transparent, tasteless, without effect on blue colors—becoming pulverulent with a mild heat, and with ignition, exhales silicated fluoric acid gas. Both the powder and the jelly effervesce vigorously with sulphuric acid.

Caustic potash, soda and ammonia, in the cold, do not decompose it in 24 hours; potassa and soda dissolve it with heat.

It is not possible, by potash, to extract pure silica from silicated fluoric acid gas, for it forms with it an insoluble triple salt. Gay-Lussac and Thénard, in Recher. Ph. Ch. T. II, p. 20.

* The effect of soda upon the acid fluate of silica, is very different from that of potassa. There is no prompt precipitate, but boiling produces readily a transparent jelly of pure silica, while the fluid is pure fluate of soda. In this manner, pure silica may be advantageously prepared even from the insoluble fluate of silica, which is completely decomposed by soda, with the same results as are obtained from the acid fluate.—*Id.*

† First Principles, Vol. II, p. 168.

‡ Ammonia affects the acid fluate of silica in a manner very different from potassa, and even from soda. It promptly precipitates pure gelatinous silica, opake, and white, but a little silica remains in solution in the fluate of ammonia, as appears from its repeated precipitation, on the addition of pure ammonia, from time to time, after evaporation.

Ammonia also decomposes the solid acid fluate of silica, as perfectly as the fluid.

Pure silica then can be obtained by ammonia, from either of them, although we cannot in this way obtain a pure fluate of ammonia, as we do a pure fluate of soda in the parallel process with that alkali.—*Id.*

(*b*.) *Saturate pure liquid fluoric acid with caustic or carbonated ammonia;* it is at first neutral, but by evaporation becomes acid, and does not crystallize.

2. PROPERTIES.—*By* a continued *heat it evaporates, in thick white vapors;* the taste is sharp.

It is a useful fluate, being in a convenient form to be employed as a test of lime, &c.

FLUATE OF BARYTA.*

1. PROCESS.

(*a*.) *By mingling pure fluoric acid with barytic water, solid pure baryta, or the native or artificial carbonate.*

(*b*.) *To nitrate or muriate of barytes, add fluoric acid, or any alkaline fluate.*

2. PROPERTIES.

(*a*.) *A pulverulent, fleecy precipitate,* sparingly soluble in water, decomposed by lime water, and by sulphuric acid.

(*b*.) Soluble in an excess of fluoric acid, and in the nitric and muriatic acids.

(*c*.) Sometimes fluoric acid is used to distinguish between lime and baryta, because the compound with the latter is more soluble than with the former.

FLUATE OF STRONTIA.

Substituting strontia and its soluble salts, for baryta and its similar salts, the facts with respect to this fluate are the same as with respect to the preceding, and their properties are very similar.

FLUATE OF LIME.

Remark.—As the native fluate of lime exists in abundance, there is no occasion to form it by art.

1. PREPARATION.—It may however be done, by processes perfectly analogous to those which have been stated with respect to baryta and strontia, substituting lime water, with fluoric acid, or better, the soluble salts of lime, with solutions of the alkaline fluates; perhaps the best is fluate of ammonia, with nitrate of lime; the insoluble precipitate is washed and dried.

2. PROPERTIES.

(*a*.) *Lime and fluoric acid reciprocally take each other from every thing else,*† and are therefore mutually tests; the soluble alkaline

---

[*] If the acid fluate of silica be poured into a solution of the muriate, or nitrate of baryta, in a few minutes a multitude of small crystals are precipitated; they are very hard, insoluble in water, and in nitric and muriatic acids, and suffer no alteration from being heated with lampblack. There can be no doubt that they are a triple compound of fluoric acid, silica, and baryta.

[†] Some doubt is intimated relative to fluate of magnesia.—Aikins, Dict. Vol. I, p. 441.

fluates are generally used for this purpose, especially the fluate of ammonia.

(b.) *Soluble in fluoric acid*, and in the nitric and muriatic.

(c.) *The native fluate is phosphorescent on hot iron.*

(d.) *Insipid—not affected by air—at* 51° *W. fuses into a transparent glass.*

(e.) *Decomposed by sulphuric acid, with evolution of fluoric acid gas*, as already stated.

NATURAL HISTORY.—This belongs to mineralogy, and the uses of the mineral to the arts; but it may be briefly stated here, that hitherto only one mine has been discovered that affords the massive fluor, in pieces of sufficient size and firmness to admit of their being wrought. This mine it at Castleton, in Derbyshire, England, and is called the spar mine.‡ I saw it in 1805, when it was far from being exhausted.

FLUATE OF MAGNESIA.

1. PREPARATION.

(a.) *Carbonate of the earth and liquid fluoric acid*, with a mild heat; there is effervescence; near saturation, the salt falls down chiefly in a gelatinous precipitate, probably mixed with silica.

(b.) *Soluble salts of magnesia, mingled with liquid fluoric acid* or with solutions of alkaline fluates.

2. PROPERTIES.—*Scarcely soluble in water*; rather more so in alcohol; not decomposed by heat, nor by any acid, but soluble in the strong acids.

The Brucite, or Condrodrite contains a native fluate of magnesia.

FLUATE OF ALUMINA.

1. PROCESS.

(a.) The earth precipitated from alum is soluble in fluoric acid.

(b.) Alum and alkaline fluates decompose each other, and produce fluate of alumina, and sulphate of alkali.

2. PROPERTIES.

(a.) The pulverulent compound becomes gelatinous by evaporation, but does not crystallize.

---

‡ In that mine, it is not, as every where else, mixed with other spars, and with metallic matters, but constitutes entire veins by itself; these veins lie imbedded in solid limestone, and are wrought for the sake of the fluate of lime only, which is manufactured into articles of furniture, as candle sticks, salt-cellars, ink stands, &c., and into the most beautiful ornaments for houses and palaces, as urns, vases, pyramids.

In this mine, attached to the walls and roofs, are the most beautiful crystallized incrustations, and regular stalactites of carbonate of lime, some of which last have reached the floor, and form continued pillars, and as they, and the incrustations are generally of a snowy whiteness, they present a very brilliant spectacle when those dark regions are lighted up with candles.

(*b.*) *Insipid, insoluble in water, but soluble in an excess of acid.*
(*c.*) *The compound of alumina, fluoric acid, and soda, may be made to crystallize, and is even found native in the cryolite; and in the topaz, fluoric acid is combined with fluoric acid.*

The properties of the fluate of silica have been incidentally detailed, perhaps to a sufficient extent. The following facts may however be advantageously recapitulated.

FLUATE OF SILICA.

1. This compound is always formed when fluoric acid is obtained in glass vessels; more perfectly if a little powdered flint or sand be mixed with the materials.
2. Silica is thus suspended in the gaseous form, and is permanent over quicksilver.
3. Water throws down a part of it.
4. Glass vessels are corroded both by liquid and gaseous fluoric acid; Bergman obtained crystals from a fluoric solution, which Fourcroy regards as fluate of silica.
5. Alkalies decompose the fluate of silica, and triple compounds are often thus formed.
6. A similar compound is formed when fluoric acid attacks glass; softer siliceous stones that contain no alkali, are attacked by fluoric acid, with more difficulty.
7. Fluate of silica is decomposed by heat.

Remarks.—It is very probable that the progress of chemical analysis will bring to light more native combinations of earths, with the fluoric acid; a number have been added within a few years.

Gay-Lussac and Thénard remark, that they had a quantity of fluor of the purest and most beautiful appearance, in which the eye, aided by a magnifier, did not enable them to discover any silex, which nevertheless yielded silicated fluoric acid gas.

The fluates of zirconia, glucina, and yttria are formed upon the same principles as the other earthy fluates, but are of no importance.*

SEC.—VIII.—SELENIUM.

1. DISCOVERY.—*By Berzelius, in* 1818. The iron pyrites of Fahlun, in Sweden, afford by sublimation, sulphur, which being employed in the manufacture of sulphuric acid, a reddish substance† was constantly deposited in the bottom of the leaden chambers. It was principally sulphur, but on burning it, an odor like that of decay-

---

* See Recher. Phys.-Chim. Tom. II, p. 27.

† In this substance, besides the selenium, Berzelius found mercury, tin, copper, zinc, iron, lead, and arsenic.

ed horse radish was perceived, and on closer examination, a peculiar substance was discovered, to which the name of selenium was given. It has been discovered in the form of sulphuret of selenium, among the volcanic products of the Lipari islands; at Clausthal, in the Hartz mountains, in combination with lead, cobalt, silver, mercury and copper; in several varieties of sulphur, in the sulphuric acid of Nordhausen, and in that manufactured from the sulphur of pyrites, from the isle of Anglesea.

2. Name.—*From* Σεληνη, *the moon*, in analogy with tellurium, from *tellus;* the substance having some resemblance to tellurium, and having at first been mistaken for it by Berzelius.*

3. Process.—The process of Berzelius being very long, the shorter one of Lewenau is here abridged.

The red deposit 1 lb. is placed in a 2 quart tubulated retort, whose sides must not be soiled; it is placed in the sand bath, and connected with a large globular receiver, joined by a Woulfe's tube, to a flask full of water, and all properly luted.

Nitro muriatic acid, composed of 8 muriatic, sp. gr. 1.2, to 4 of nitric, sp. gr. 1.5,† was now introduced by portions, to the bottom of the retort, intervals being allowed for the subsidence of the effervescence, and of the heat.

Red vapors escaped, the liquid in the retort became dark gray, and that in the Woulfe's bottle, reddish yellow.

The fluid being distilled over in the retort, a reddish yellow gas was disengaged, and near the end, small yellow stellated crystals lined the neck of the retort, which disappeared with the increase of the heat; most of the liquid having thus passed, more acid was added in portions, and a violent action ensued at every addition, the water in the flask being several times changed, as it became saturated with the acid vapors. All the liquors being redistilled from the retort, an insoluble residuum, of a deep red color, supposed to be selenium, now occupied its bottom and sides. To dissolve it, 1½ lbs. of fuming nitric acid was next added, and distilled nearly to dryness. The residuum was then washed with boiling distilled water, till it came off tasteless, and the filtered fluid was of a light yellow.‡ This fluid contained the selenium in the form of selenic acid, and to precipitate it, (neglecting the metals that might be in solution,) recently prepared sulphite of ammonia, in large excess, was added, which threw down the selenium in the form of large cinnabar colored flakes. When the solution was strong, the precipitation was immediate; if dilute, it was more tardy, and the color varied from bright red to dark gray. The selenium was washed with 5 or 6 parts of cold distilled water, till muriate of baryta gave no precipitate, and lastly, it was dried in the shade.

---

* See Ann. de Chim. et de Phys. Vol. IX, and Ann. Phil. Vol. VIII, N. S. and Vol. XIII.

† The author speaks of 12 lbs. of the mixed acid, but this seems disproportioned to the size of the retort.

‡ The distilled fluid was found to be slightly seleniferous.

The selenium still contained in the liquor is obtained by concentration, by evaporating to two thirds the bulk, and the addition of more sulphite of ammonia, and finally by immersing bars of zinc, taking care that these do not remain in too long, and thus mix their own substance with the selenium.*

4. PROPERTIES.

(a.) *Color various; if rapidly cooled, dark brown, or gray, or of a leaden color, and metallic lustre,* it often resembles polished hematite; when in powder of a deep red, adheres by pounding, and its surface gray and smooth.

(b.) *It is not hard, but it is brittle;* fracture conchoidal, of the color of lead, and perfectly metallic; lustre vitreous.

(c.) Sp. gr. between 4.31, and 4.32.

(d.) *At 212° soft and ductile,* like Spanish wax, and may be kneaded between the fingers, or drawn into fine translucent threads, which have a metallic aspect; "red by transmitted, but gray by reflected light." Becomes quite fluid, at a temperature considerably above that of boiling water, and near that of boiling mercury, or about 650°, it boils, and may be distilled in a retort, condensing like mercury, in metallic drops, or if a retort with a large neck is used, or sufficient space to mix it with cold air, in a light sublimate, of a fine cinnabar color. Its vapor is of a color between that of chlorine, and that of the vapor of sulphur. If cooled slowly, it assumes a granulated fracture, like that of cobalt.

(e.) *At the boiling point its vapor is inodorous; but under the blowpipe a piece not over* $\frac{1}{50}$ *of a gr. will fill a large room with the smell of horse radish:* it tinges the blowpipe flame of a fine azure blue.

(f.) Insoluble in water; not altered by the air.

(g.) *A non-conductor of heat and electricity, and does not become electric by friction.*

OXIDE OF SELENIUM.

(a.) *The peculiar odor* is developed when the exterior flame of the blowpipe is applied, and *is caused by the combination of selenium*

---

* The sulphureous deposit examined by Mr. Lewenau was from a sulphuric acid manufactory, in Hungary: it was much richer than that of Sweden, and afforded 591.82 grs. to the pound of the crude substance, of which 484.16 was from the first precipitate.—Ann. Phil. N. S. Vol. VIII, p. 106. In one instance, the material of Sweden gave Berzelius only 0.0015 of its weight.

*with oxygen, forming a gaseous oxide of selenium,** and like arsenic it is odorous only while combining with oxygen at a high temperature.

(*b.*) *Formed best by heating selenium in a close glass vessel, with a limited quantity of air*, which is to be washed to remove the selenic acid, a little of which is formed at the same time; the water acquires the smell of the gas, and feebly reddens litmus.

The oxide of selenium is only sparingly soluble in water, and does not combine with alkalies. Its composition has not been ascertained, but it is supposed to be one proportion of each of the constituents.

SELENIOUS ACID.

1. PROPERTIES.

(*a.*) *Selenium is combustible. Heated in a flask filled with oxygen gas, selenium evaporates with the odor of oxide of selenium, but without inflaming,* and exactly as it would do in common air; *but if heated in a glass ball* of an inch in diameter, *and supplied with oxygen gas* at the moment of ebullition, it burns with a feeble flame, white towards the base, and green, or bluish green on the edges: the selenium is completely consumed, oxygen gas is absorbed, and the remaining gas has the odor of oxide of selenium. The product is a sublimate of selenious acid.

(*b.*) *Hot nitric acid dissolves selenium,* and forms on cooling large prismatic crystals of *selenic acid,* longitudinally striated, and resembling almost exactly those of nitrate of potash.

(*c.*) *This acid is still better prepared by the aid of nitro-muriatic acid.* A white residuum is left on evaporation, and by an increased heat the selenious acid sublimes, and is condensed in the colder part of the apparatus in very long† needles of four sides. The vapor of the acid has a deep yellow color much resembling that of chlorine, but not so deep as that of the vapor of the selenium itself.

(*d.*) *Selenious acid has a peculiar lustre which it quickly loses on being exposed to the air;* the crystals adhere and *it gains weight so fast that it is difficult to weigh it accurately. Taste acid, leaving a slightly burning sensation.*

(*e.*) *Readily soluble in cold and almost without limit in hot water,* from which, by rapid cooling, it crystallizes in grains, and more slowly in prisms, and spontaneously in acicular radiated groups. Very soluble in alcohol and giving with that fluid by distillation an etherial odor, intermediate between that of nitre and sulphuric ether.

(*f.*) Sulphuric acid, selenic acid, and alcohol in mixture produce by distillation, a most insupportable odor. *Decomposition. Easily af-*

---

* Which Berzelius thinks analogous to the oxide of carbon, although he has not been able to isolate and shew it separately.

† In a large retort they are sometimes two inches or more long.

fected by all bodies having a strong affinity for oxygen, as sulphurous and phosphorous acids, alkaline sulphites, and sulphuretted hydrogen, and metallic zinc,* by all of which it is precipitated. *Zinc throws it down in the form of red, brown, or blackish flakes:* sulphuretted hydrogen in an orange precipitate, fusible a little above 212°, sublimed in close vessels, burning in the air and producing selenic and sulphurous acids.

(*g*.) *Selenium is soluble in oils;* it unites with the metals usually with ignition, forming seleniurets commonly of a gray color and metallic lustre. The seleniuret of potassium is soluble in water with effervescence. The acids disengage from it seleniuretted hydrogen, whose odor is like that of sulphuretted hydrogen but excessively offensive. This gas is soluble in water, combines with the alkalies, and precipitates metallic salts of a dark color.

2. Equivalent number.—Berzelius from his investigations concludes that selenious acid consists of

Selenium,	71.261	100.00
Oxygen,	28.739	40.33

If it is composed of one proportion of base and two of oxygen, the equivalent number of selenium will be 40+2 *oxygen* 16=56 *for the equivalent of selenic acid.*

SELENIC ACID.

The acid just described has been hitherto called by this name, but another acid has been discovered containing an additional equivalent of oxygen, and which is therefore called *selenic acid.*

1. Preparation.—Omitting the tedious process upon the selenitic ores,† we may describe that which commences with the preceding acid, the selenious.

(*a*.) It is neutralized by soda, and by fusion with nitre or with nitrate of soda it is converted into seleniate of soda and crystallized.

(*b*.) This seleniate is decomposed by nitrate of lead, which gives an insoluble seleniate.

(*c*.) This is decomposed by a stream of sulphuretted hydrogen, which precipitates the lead as a sulphuret and liberates, without decomposing the selenic acid; the excess of sulphuretted hydrogen being expelled by heat, the selenic acid remains diluted with water.

2. Properties.

(*a*.) *Colorless; not decomposed below* 576° *Fahr. but above that emits oxygen and becomes selenious acid.*

(*b*.) *Sp. gr.*—When concentrated at 329°, it is 2.524; if at 512°, it is 2.60; and if at 545°, it is 2.625; but a little selenious acid is then present. Concentrated at a heat above 576°, and deducting the selenious acid present, it appeared to contain 15.75 water.

---

* Mixed with muriatic acid.

† Edin. Jour. of Science, No. XVI, p. 294, and Turner, 2d ed. p. 850.

(*c.*) *Attracts water powerfully, and by combining with it, evolves as much heat as sulphuric acid.*

(*d.*) *Boiled with muriatic acid, selenious acid is deposited and chlorine liberated, and the solution dissolves gold* but not platinum; it resembles *aqua regia*, and probably contains it.

It unites with alkaline bases and forms salts, which are with difficulty decomposed by sulphuric acid, which it appears strongly to resemble.

(*f.*) Selenic acid dissolves iron and zinc, with disengagement of hydrogen gas.

3. Its equivalent.—It appears to contain 3 equivalents of oxygen, 24+1 of selenium, 40=64.

Classification.—Selenium resembles the metals in sp. gr., and metallic lustre, and in most of its chemical properties, but it is a non-conductor of heat and electricity. Berzelius ranked it with the metals, and it has a considerable resemblance to tellurium, but it is rather more like sulphur, and on the whole seems to form a connecting link between the combustibles and the metals. Its combination with hydrogen appears to be particularly noxious, and it is probable that it often renders sulphuretted hydrogen more noxious, since there is reason to believe that it is not unfrequently present in that gas, as sulphur is often contaminated by it. It is obtained by heating the seleniuret of iron with muriatic acid, by an obvious theory. The gas is acid and has been called *hydro-selenic acid and seleniuretted hydrogen.* It is colorless, fetid, irritates and paralyses the membrane of the nose for some hours, so that the sense of smell is destroyed; it is dissolved by water and stains the skin brown. It is decomposed by the air and leaves selenium. With all the metallic solutions it forms seleniurets.*

Selenium being as yet a substance very difficult to be obtained, we must refer, for numerous additional particulars and for the history of the *seleniates*, to the elaborate memoir of Berzelius, in the ninth volume of the Annales de Chimie et de Physique.

---

* Turner, 2d ed. p. 356.

END OF VOL. I.

3 2044 019 356 427

THE BORROWER WILL BE CHARGED AN OVERDUE FEE IF THIS BOOK IS NOT RETURNED TO THE LIBRARY ON OR BEFORE THE LAST DATE STAMPED BELOW. NON-RECEIPT OF OVERDUE NOTICES DOES NOT EXEMPT THE BORROWER FROM OVERDUE FEES.

WIDENER
BOOK DUE
CANCELLED
NOV 6 - 1987
NOV - 4 1987

2420415

WIDENER
BOOK DUE
CANCELLED
DEC 4 1987
DEC 2 4 1987

2446513

WIDENER
BOOK DUE
SEP 1 0 1997
WIDENER
CANCELLED

WIDENER
BOOK DUE
SEP 1 0 2001
WIDENER
NOV 1 0 2001
CANCELLED

5772687

CANCELLED
JUN 1 1 197
JAN 6 1974
CANCELLED
DUE MAR 74 H

4201863

3619